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*Personal Observations on Terraces, and other Proofs of Changes in the Relative Level of Sea and Land, in Scandinavia.**

By Robert Chambers, Esq., F.R.S.E. and V. P. S. A. Sc.

(With a Plate and Map.) Communicated by the Author.

The remarkable proofs which Scandinavia affords, of changes in the relative level of sea and land, have for many years attracted the attention, not only of the native, but of several eminent foreign geologists. The observations made by these inquirers are more or less generally known. They refer to beds of shells, identical in species with those of the present coasts, in parts of the country far inland, and elevated considerably above the present sea level; remains of serpulæ, balani, and other marine animals, adhering to the rocks in certain inland situations; terraces at different heights above the sea, which have evidently been formed by that element, whether appearing as detrital deposits, charged with shells or otherwise, or as indentations in rocky coasts, a result of the wearing agency of the waves. Attention has also been drawn, as is well known, to an apparent rise of parts of the Scandinavian Peninsula towards the south, at a slow but steady rate; a phenomenon in which we seem to have presented to our living eyes some remains of that force, whatever it is, by which the greater changes of ancient times were effected.

In a tour of Norway and Sweden, during the summer of the present year, I had an opportunity of making some personal observations on the phenomena connected with the changes of the relative level of sea and land; and of these I shall lay an account before the Society, along with a few illustrations which may be of service in helping out description.

I shall first allude briefly to a few elevated alluvial formations in the southern part of Norway.

At the head of one of the branches of the Christiania fiord, where the busy mercantile town of Drammen is situated, a river, named, from its clayey banks, Lir, enters the sea.

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* Read before the Royal Society of Edinburgh, Dec. 3, 1849.

HOIÖE

SORÖE

Hammerfest

85
87
89
91
96
104
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107
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130
137
143
154
161
170
179
205
239

Rypefd

Saragamma

QUALÖE

Akkerfd

Molstrand

Quisnaes

Indre Sioholmen

Qualsund

Reppefiord

Komagnaes

Berutsmol

Line of Axis of movement

Norvegr d

Rabastinaes

SEILAND

VARG SUND

Quaenklubb

Oldersfd

Saraby

Stor Bekkar fd.

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MAINLAND

STIERN ÖE

Komagfd

Kortsfd

Meridian of Dip.

Lang fd

A L T E N F D

Talvig

Melvig

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Kaafjord

Oskarnaes

Quaenvig

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These banks, for several miles from the embrochure of the stream, are composed of terraces of clayey alluvium, rising above each other to the height of several hundred feet. In some instances, I succeeded in ascertaining that these were of corresponding heights on the different sides of the river. Some of them persevere for several miles along the valley at one uniform height. I therefore considered them as roughly indicative of stages or pauses in the change of the relative level of sea and land. Taking as a basis the surface of the sea, which is here at its mean level, I found, by careful measurement with the level and the staff, that two of the most distinct and persistent of these terraces were respectively of these heights, namely, 77 and 98 feet; taking in both instances that point in the sectional outline of the terrace, where the moderate inclination of its surface gives place to a new rise. A very distinct portion of this latter terrace runs along under a country-house called Nystad, and towards one called Rudd House.

The valleys of those affluents of the Glommen River, which are crossed on the road from Christiania to Trondheim, are full of alluvial terraces of various materials. That of the Nytte River presents terraces of sand; that of the Leer River (a different river from the Lir above mentioned) affords terraces of clay; and hence, no doubt, the name given to the stream. The appearance of these terraces, broken into short spaces by side streams, and often having farmsteads perched on the detached pieces, while the banks in front descend at a deep inclination to the bottom of the valley, produces scenery of a peculiar and striking kind. The pass from this valley to the next, in which runs the river issuing from the Miösen Lake, is a broad flat space composed of a bed of water-worn gravel, with pieces as large as a man's head; and this flat is several hundred feet above the level of the sea.

The valley, containing the river issuing from the Miösen Lake, is several miles broad, between hills of no great elevation; yet it is filled from side to side with a formation, at least topped with pure sand, generally flat, and extending with a slight rise up to the lower extremity of the lake, which

it embraces in a beautiful curve, rising in a steep bank about 240 feet above its waters. The outlet of the lake is through a deep trench in this formation. In the neighbourhood of the lake, the sandy plain rises towards the hills on each side, at a gentle inclination, and with a remarkably equable surface, like a sea-beach. What adds not a little to this resemblance is a fringe of gravel at a greater inclination, abutting against the hill-side. Taking the height of the Miösen Lake on the day of observation at 420 feet above the sea, the utmost elevation of this ancient sea-margin above the present sea-level appears to be about 656 feet. In the inner valley or trench, cut by the river, there are minor terraces, at respectively 522, 533, and 598 feet above the sea. A few miles down the valley, at the Trygstad post-station, a great terrace is seen passing for several miles at one level along the hill-side, rendered the more conspicuous by the bright line of green formed by its grassy turf, in contrast with the dark hue of the woods which rise immediately from it to the very summits of the hills. With the spirit-level, I found the line of this terrace to be about the same height with Trygstad station, which is given as 590 Rhenish feet above the sea, in Professor Keilhau's *Goea Norvegica*. As this is an unusually distinct example of the ancient beach, it is very desirable that its elevation were more exactly ascertained. Meanwhile, we may be tolerably satisfied, when we allow for the difference between Rhenish and English measure, that it is nearly, if not quite, identical in height with the terrace just spoken of as 598 feet. It may also be remarked, that the Scandinavian geologists report upon an ancient beach of 597 feet at Lake Oyeren, a lower portion of this group of waters, distant only a few miles from Trygstad. It might be worth while to inquire if any connection can be established between these terraces.

These ancient sea-markings will be the less liable to challenge on the part of my present audience, when I remind them of the conclusion arrived at several years ago by the geologists of Scandinavia, that there are proofs, in terraces and shell-deposits, of that peninsula having been upraised from 600 to 700 feet, at a period immediately preceding the

historical era. There are not wanting, however, evidences of a similar nature, that the relative level of sea and land has, in Scandinavia, undergone a much greater change.

The valley of the Rauma, which opens upon the west coast, and that of the Logan, an affluent of the Glommen, which pours itself into the Baltic, meet in a trough of country in the Dovre field, the summit of which is occupied by the *Lässö-verks vand*, 2045 feet above the sea. By an extraordinary natural arrangement, the lake emits the Rauma at one end and the Logan at the other; so that a portion of Norway is completely enclosed by natural water. The valley of the Logan, for several miles down, contains great masses of pure sand, in the form of terraces and isolated mounts. On one of the latter, Dovre Church is situated, at an elevation of 1543 feet. In this portion of the valley, there is a terrace unlike the rest, in as far as it is a narrow ledge of detrital matter, running continuously along the hill-side for fully 14 miles, however much more, while the terraces resting on the skirts of the hills lower down are great projecting masses, seldom extending far on one level. This remarkable terrace is most conspicuous on the right or south-west side of the valley. It begins on that side at Oue, between the Hougen and Tofte post-stations. It is there seen truncating the prominent ancient delta of a side stream, called, in Professor Munch's map, the Jondal's Elv, several hundred feet above the bottom of the valley. As we ascend the valley, it becomes nearer to our eye; but this is only because we rise to it, for, when examined with a correct instrument from its own elevation on the opposite side, it is proved to be for a great way truly horizontal. On the left or north-east side of the valley, the corresponding mark is a line composed of slight projecting banks of water-laid sand. Though not continuous, this line is sufficient to have determined that of a long mountain-path connecting a series of farms. Beyond Lie post-station, the road to Molde passes along it, and it here affords positions for a close series of hamlets, which make a conspicuous appearance in the map above cited. I believe it is nearly, if not exactly, of the same elevation with the little *hof*, called

Dombaas, of which the height is given by Prof. Naumann as 2162 (English) feet. In its relation to the lakes in the summit between the two valleys, it precisely resembles the lowest of the Inverness-shire *parallel roads*, as exemplified in Glen Spean, where advancing to the basin of Loch Laggan, between the Spean and Spey valleys. The terrace in every other respect bears a strong resemblance to the Inverness-shire *roads;* while in some important respects, as already noted, it differs from other terraces. I should much desire to see it obtain the attention of local observers, by whom its internal constitution and other features could be more particularly ascertained. Meanwhile, it is not unworthy of remark, that on a neighbouring portion of the plateau of the Dovre field, between two and three thousand feet above the sea, there are peat mosses containing remains of much larger trees than now grow in the district, the vegetation of which does not ascend above a dwarf birch. If the terrace were at one time upon the level of the sea, this plateau would of course enjoy a climate equal to that of districts of a few hundred feet of elevation, and it might then be well able to raise such pieces of timber as now lie ruined in the mosses.

The city of Trondhiem lies at the opening of the valley of the Nid, with high grounds on the east side, and a bold cliffy hill overlooking the sea on the west. Close to the town, and along the valley for several miles, there are terraces of clayey material, none of which persevere for a great way. From indeterminateness of form, and partly of level also, it is impossible to state their elevations with great distinctness; but I may mention, for the sake of general description, that, on sighting them with the telescope-level across the country, they exhibited lines, more or less definite, at about 60, 111, 145, 253, and 435 feet. The most interesting object of the kind is a terrace of erosion, on the face of the cliffy hill to the west of the city. This is an extraordinary and most impressive example. It extends for miles along the face of the hill, at one uniform elevation, which I ascertained with the level and staff to be 522 feet above the

sea. Seen from the opposite side of the valley, or from the streets of Trondheim, it appears as a dark band across the hill-face. On near inspection, we find a deep cut into the almost horizontally disposed slate-rocks, with a ledge, flat though rough, at some places as much as twenty paces broad, while overhead rises a cliff more or less bold, formed of the angular edges of the broken strata, with here and there a modern talus descending upon the terrace. Not the least doubt can exist, that it is the effect of the working of the sea, when this part of the hill was on a level with the waves. On the opposite coasts of the Trondheim fiord there are marks of a similar terrace at apparently about the same elevation. The drawing here exhibited presents the appearance of the terrace above the city of Trondheim, at a place where its floor is well defined and flat, and the cliff nearly vertical, and certainly not less than forty feet high. Directing our eyes to the southward, we here see a hill about a mile off, called Sverrosborg, because King Sverro, a distinguished Norwegian monarch of the twelfth century, had a fort upon the top of it. This top is composed of a mass of bare rock about thirty feet high, starting up out of the green-sided hill. The terrace of erosion is marked all round under the mass of bare rock, producing a curious and quaint appearance. The sea has manifestly worn out this terrace at the time when it produced the line of erosion on the neighbouring hill-face, for it is precisely of the same height. Some of the neighbouring grounds come to about the same level, as if produced by a contemporaneous silting-up of these spaces to the surface of the sea.

Connected with this terrace of erosion there are some remarkable alluvial terraces in the interior of the country. A few miles to the south-east of Trondheim, the road leaves the Nid valley, and passes into that of the Gula, a powerful river which discharges itself into a neighbouring branch of the fiord. The country over which the road passes between the two valleys, is a spacious moor, composed of detrital matter, and very flat. Its general elevation is about the same height with the great terrace of erosion. When we advance into the Gula valley near the post-station of Oust,

we see a terrace commencing along the east side of the valley, and persevering at one height for a considerable way, being just about the same elevation with the aforesaid moor. This terrace is clearly of the same kind with that in the Logan valley, not a product of fluviatile deposits, as so many terraces are, but of the long-continued washing of the sea against a mountain-side. Descending into the Gula valley, we find vast alluvial deposits, generally of a muddy character, and sometimes terrassiform. Their composition changes as we advance to a fine sand; and this again begins to shew a gravelly admixture, the light materials having, as usual, been carried farther than those of a heavier nature. Near the Meelhuus post-station, which is 123 feet above the sea, there is a sand terrace fully 200 feet high, and from the face of which the material rises in a cloud with every gust of wind. The comparatively low terraces, resting in huge masses on the skirts of the hills, continue for several miles to be very conspicuous, while the higher line on the hill-faces is no longer traceable. At length, between the Leer and Vollan post-stations, and about 25 miles from Trondheim, a highly-remarkable alluvial formation is observed upon the left or west side of the valley. It has a surface perfectly flat, and perhaps an English mile broad, abutting against the hills behind, and in front descending in a steep grassy bank to the river's brink. It extends for miles along the valley, always preserving one elevation, while a terrace of the same height, but less persevering, is seen on the opposite side. The termination in the downward direction of the valley is abrupt, as if the terrace had been broken down at a certain point by the retiring sea; and here there are seen, on the face of the bank below, five several minor terraces, extending only a short way. The accompanying sketch will convey a more lively, though still imperfect, idea of these objects. I am unable to speak with precision of the height of this grand alluvial terrace; but, from my observation of its elevation above the Vollan station, which is set down as 310 feet by Mr Keilhau, I deem it not unlikely that it will prove, on examination, to be coincident with the aforesaid line at Oust, and the terrace of erosion at

Trondhiem. This is the more likely, from what may be observed at Soknaes, the next post-station in the valley. There is here a wide space formed by the junction of a branch valley. The whole space within sight might be described as a *nest* of alluvial terraces, reaching to a considerable height above the two rivers. At one spot, near Soknaes, as many as six are seen rising above each other, the inn being placed on a promontory formed by the fourth of the series. A connection between this group of terraces and that at Vollan is obscurely traceable along the valley. By M. Von Buch, the elevation of the Soknaes station is set down at 487 feet; and hence, I presume, that the sixth or highest terrace at that place may be about the same elevation with the Trondheim line of erosion, or 522 feet. It is desirable that a careful examination of the whole of the Gula markings should be made, and their levels ascertained, in order to ascertain how far they observe uniformity, and if any of them be truly identical in elevation with the Trondheim terrace of erosion, as here surmised from observations which I am sorry to find so much more vague than was to be desired.

On the Sokna, the branch of the Gula here spoken of, there is a similar system of alluvial terraces, on one of which the church of Soknadalen and post-station of Hof are situated. It may be remarked, however, that such terraces, though evidencing a shift of the relative level of sea and land, are not always exact marks of the point at which the sea and land formerly met. Where found sloping in the line of the valley, as is the case with several at Hof, they may be regarded as only the ancient haughs of the river before the withdrawal of the sea (so to speak) allowed it to cut down its alluvial deposit, and seek a lower channel. Where, on the other hand, an alluvial terrace is of the character of that at Vollan, not only broad and flat, but extending a long way upon one level, experience teaches me to expect such relations of measurement as indicate its being the true mark of an ancient line of coast. Among the Soknadalen terraces, I find that I have noted that on which the post-station and church are situated as alone answering the requirements of an ancient sea-level, making the additional remark, that the

exact site of Hof is probably a few feet lower, as not being at the highest point of the terrace. By M. Von Buch the elevation of Hof is given as 945 Paris feet above the sea; by another observer it is placed somewhat lower. The mean, given by Professor Keilhau, is 960 Rhenish feet. It appears probable, that the former relative position of the sea is, in this instance, elevated between 990 and 1000 English feet.

I have now to lead attention to the shores of the provinces of Nordlands and Finmark, only previously remarking, that in the intermediate coast there are no terraces of any kind visible from the open sea, there being, in reality, scarcely any detrital formations there, while the rocks are so smoothed by glacial action, as to have afforded little inlet to the erosive power of the waves. It is not till we reach the Island of Hindöe, one of the Lofoden group, that any such markings are presented. In Raft Sund, on the south-west side of that island, about latitude 68° 20′, two faint terraces of erosion are traceable. They are also seen on both sides of the strait between the island and the mainland. At Trondinaes, the northern point of the island, where there is a recess of comparatively soft ground in the iron-bound coast, these two lines are more conspicuous, forming indentations in the grassy slopes; while, in the rocky cliffs, they appear as strongly-marked terraces of erosion. A rough little island, called Magöe, at this place, is cinctured with these terraces of erosion, exactly like the hill of Sverrosborg, but in a more marked manner, for here the waves of the ancient sea have had to deal with strata of unequal hardness; therefore, some masses are left starting up in sharp ridges and rude columns above the general floor of the terrace, which is nevertheless sufficiently well-defined. In all circumstances, the two lines seem to preserve their respective heights undeviatingly, the one being apparently about 50 feet high, and the second 100 feet higher.

In an inlet of the Island of Anderiöe, a few miles from Hindöe, I observed three terraces at a place called Ibbestad, all apparently under 100 feet, and therefore, presumably, a different system from those hitherto noticed.

Farther north, after passing the great inlet of Balsfiord, we

find in Trom Sund, the two former terraces resumed. I have been informed, however, by a gentleman of Tromsöe, who has given some attention to the terraces of the district, that there are several distinctly traceable in Balsfiord, one of them at the height of perhaps 400 feet above the sea.

In Trom Sund, the faces of the hills are soft and green, and the two terraces appear as slight, but distinct indentations in the grassy slope, never failing to preserve to all appearance, one relation of levels. It is remarkable, that, while clear and conspicuous on both sides of this narrow sound, they are scarcely to be traced on either side of the interjected island of Tromsöe. On the north-west side of the sound, behind the island, there is a faint appearance of a third terrace upwards of 100 feet above the second. Of the two distinct terraces I took a measurement with the level and staff, and found them to be respectively 57 and 143 feet above the highest tide-mark. Another observer, M. Siljestrom, has given measurements of them slightly different, namely, 56 and 149 feet, and has added the elevation of a third, which I did not succeed in seeing, at 220 feet.

In the range of sounds through which the post-steamer passes, in the sixty-ninth degree of latitude, I observed the two lines well marked on the green skirts of the hills, with scarcely any interruption. The continuity from island to island is very remarkable. Sometimes there is an escarpment or a line of exposed rock, to render the ancient sea-mark the more distinguishable. All along there seems to be not the slightest departure from one set of levels. In recesses, where perhaps little rills have brought down some detritus, not only these two terraces are marked, but several intermediate ones besides. At a promontory of soft matter, called Skätoren, forming the eastern extremity of the island of Ringvatsöe, there are at least four terraces below the higher of the two already so often alluded to, besides some minute and less distinct markings. On the island of Vorteröe, at the south point, which consists of a narrow lofty rock, there is an object of an instructive character, namely, a series of terraces on one side, with a series of greater elevation on the other, shewing how it may depend

on local circumstances, as currents and perhaps prevailing winds, that any such impressions are to be made upon a coast, while the relative level is in the course of being changed.

The farthest north point to which I traced the remarkable couple of terraces is Mour Sund, fully ten hours' sail north of Tromsöe. The mountains then begin to be rough with debris, so as perhaps to have presented an unsuitable surface for such markings. M. Keilhau appears to have found the lower of the two still farther along to the north-east, namely, in Langfiord, one of the branches of the Altenfiord. The terrace which he observed in that place is set down by him at 52½ feet above the sea. The gentleman who told me of the terraces in Balsfiord, assured me of there being similar objects in Lyngenfiord, a great inlet which receives several considerable streams. A careful examination of these recesses would probably afford a rich harvest of results, and help materially to solve the problems connected with this subject.

We now approach a portion of the coast, presenting a group of terraces which has already attained some celebrity. The district in question may be said to extend from the Altenfiord, with its branch Kaafiord, into the strait called Varg Sund, which is formed by the mainland on the one side, and the Island of Seiland on the other; being afterwards prolonged into the two sounds surrounding the Island of Qualöe. Altogether it is a range of estuaries and straits extending about fifty miles in a direction generally north and south, and mostly comprised in the 70th degree of latitude. This portion of the Norwegian coast was examined in 1839, by M. Bravais of the French Scientific Expedition of the North; and the facts pointed out by him were briefly these:—

At the mouth of the river Alten, there is a terrace of sand, 223 feet above the sea, and this extends up the river, always on the same level, till, at a village five or six leagues in the interior, it is only about 91 feet above the general level of the district. At the mouth of the smaller stream, commonly called the Kaafiord Elv, a few miles from the mouth of the Alten, there is a similar sandy terrace at the same elevation

above the sea, besides a narrow shelf, " like the towing-path of a canal," about 90 feet above the sea.

Proceeding in a northerly direction, M. Bravais found at Krognaes and Talvig an alluvial terrace at 185·5, and another whose mean height was 80·5 ; and these he considered as representing the two others, though at lower levels.

Advancing in the same direction, he found at Komagfiord two lines of erosion on the faces of the mountains, respectively 169·6 and 67·3 feet above the sea.

Still further advancing, he found the same two lines on the precipices of Quaenklubb, at 162·3 and 60 feet ; at a place on the islands of Seiland and Qualöe at 139·3 and 54 feet. Finally, at Hammerfest, the two lines appeared at respectively 92·3 and 46 feet. Thus it appeared that there was a constant decline in the elevation of these markings from south to north. M. Bravais likewise observed some less distinct tracings of the same kind,—a dark-coloured band on Kongshavensfield, near Bossikop, at 128 feet ; and one further on, upon the same side of the fiord, at Sortbierg, at 81 feet ; a line of erosion between Storvignaes and Krognaes, at 126 feet, and one at Talvig of 141 feet. He regarded these as indications of an intermediate line which had failed to be expressed throughout the intermediate space, but which reappeared at Hammerfest in a terrace of about 69 feet.

It may be remarked that M. Bravais used a barometer for his measurements, adopting usually the mean of several observations, and that he took as his basis a point $0^{m}·6$ above the line formed by the sea-weed on the rocks, having found that line 64 centimètres above mean height of the sea.

M. Bravais inferred that there had been at least two distinct angular movements of elevation in the region comprehended by the terraces, the first being measurable by the difference of heights between the upper and lower terrace, and the second by the height of the lower terrace at various points above the sea. The following table indicates the amount of the first elevation :—

Points of Observation,	1.	2.	3.	4.	5.	6.
Upper Line, .	223	185·5	169·6	162·3	139·3	92·3
Lower Line, .	91	80·5	67·3	60·	54·	46·
Amount of 1st Elevation,	132	105·0	102·3	102·3	85·3	46·3

He remarked, however, that the intermediate terrace considerably alters the relative amount of the earlier and later elevations along the coast, reducing the first or most ancient to about 24 feet, making the second or intermediate movement of 22 feet, and leaving the third or most recent of 46 feet, and therefore considerably greater than the other two.

In a work published by me on *Ancient Sea-Margins*, I expressed some doubts as to the alleged inclination of the Finmark terraces, being partly led thereto by the discovery, in other parts of the earth, of uniform levels for such markings; while it likewise appeared to me that, for perfect proof of M. Bravais's positions, we should have required either evidence of greater continuity in the appearances, or measurements taken at a greater number of points. I deemed it not unlikely that the fragments of terrace which he saw at different places might be, not representative of two great lines, as he supposed, but representative of a number of lines nearly if not quite equal to the number of the points of observation. I was therefore glad when I was able to pay a visit to Finmark, with a view to making a rigid personal examination of the terraces, and with the means of measuring their elevations more accurately than had yet been done. The result I am now to bring before this Society.

The general fact of the existence of two continuous lines of erosion on the rocky coast between Kortsfiord and Hammerfest I found to be true. They appear as part of the same system of terraces with those seen farther south, or as a prolongation of them; but, unlike those terraces, they do not observe a level, for the upper line is at one end not much less than a hundred feet higher than it is at the other. It is about the middle that they bear the best resemblance to the couple of terraces in Trom Sund and elsewhere. The resemblance is chiefly in likeness of elevation. As to the material, there is a difference throughout a great part of the

space; for while the terraces towards the south are chiefly indentations in soft matter, those of Varg Sund are chiefly sections made in the rocky cliffs,—true terraces of erosion. In these northern terraces, however, the lines are in some places continued from a rocky hill-face to a soft grassy slope, changing from a cut in the rocks to a mere impression on the detrital surface, without any change in their direction or inclination. The appearance of two such markings along about twenty-five miles of coast is calculated to arrest the attention of every intelligent stranger; and even the natives, who are chiefly Laplanders, have not failed to remark them, and to attribute them to the agency of the sea, though not doubting that the sea has simply retired from two several heights at which it had formerly stood. No one on the spot seems to have ever thought it worth while to inquire whether they observe one level, or at what height they stand in any place above the sea.

When I speak of the two lines as distinct, I mean that they are so strongly marked as to be visible from a considerable distance. For example, a person standing on one side of Varg Sund, though it is fully three miles broad, can, in tolerably clear weather, easily see the lines passing along the opposite coast. (See Plate III., *Upper View.*) When narrowly inspected, those designated as terraces of erosion are found to be produced by a true mechanical incision of the rock, sometimes leaving a ledge with a precipitous cliff overhanging it, sometimes consisting only of a rough groove across the mountain-side, without any distinct ledge being left,—sometimes, again, under a form intermediate to these two in all imaginable degrees. Very frequently, when wishing to examine a portion of the line, though it may at a little distance have appeared sufficiently palpable, it is found on near inspection to be obscure and indeterminate, the eye in that case not taking in at once a sufficient amount of the line to produce a distinct impression, and the immediate objects appearing rough and confused. In other places a well-defined section is offered for inspection. For example, at one part of the prominent rock called Quaenklubb (see above view), the upper line is a terrace thirty paces broad,

a flooring flat and smooth, produced by a power which has been sufficiently strong to cut sharply through the hard slaty strata, and leave scarcely any inequalities. At the same place, in strong contrast with this marking, the lower line shews, on near inspection, only a shattering of the cliff, and a wearing of it out in vertical hollows; so that it would be impossible to say, within eight or ten feet, what is the height of that line. At a place on the south side of Qualöe island, I found appearances respecting which the following entry was made in my note-book:—"Nothing could well be more perfect than the *ledge* formed by this terrace, there being only such irregularities as were unavoidable from the various hardness of the strata; some having been so very hard as to leave a slight ridge above the line, while, in other instances, a mass was left like a gross short column standing up as a monument of what it had been originally connected with. One of these surviving masses looked much like the ruins of some old castle." At a place on the mainland, opposite to the above, I found a similar ledge, but with an irregular row of short columnar masses in front, somewhat like the obelisks designed to support a chain along the skirts of an artificial terrace, while in a vacant space arose a rough rock, round the top of which the sea had cut a circular flat, causing the upper prominence to appear like a human head rising above a broad pair of shoulders. (The picture here exhibited of the line of erosion at Trondheim gives a good idea of the section of a terrace which has a flat, well-defined floor and cliff rising above, as well as of an isolated mass cinctured by a terrace, like the object last spoken of.)

It may be remarked that, according to M. Bravais, probably reporting the observations of Professor Keilhau, "the mountains of Altenfiord and of all this part of the coast belong to the group of metamorphic rocks; but the nature of the rock differs widely, since calcareous beds are found at Storvignaes, and at Talvig, between Kortsnaes and Skillifiord, amphibolic rocks on the island of Seiland and near Hammerfest; while diallage, quartzose sandstones, and argillaceous schists, are not rare." M. Bravais adds, that he was not able to judge of the influence of these rocks on the

different phenomena of the neighbourhood. I may further remark that the only general feature that seems likely to have told in making the mountains along the sea susceptible of such impressions is the fact of its being an inland sea. The direction of the various sounds and estuaries can scarcely be supposed influential, as, in fact, the markings are made upon coasts in a great variety of directions.

With the assistance of Mr Paddison, civil engineer, who was so kind as to associate himself with me in my examination of these terraces, I executed a series of accurate levellings at about eighteen points along the space between Hammerfest and Kortsfiord, and completely convinccd myself of the reality of the inclination, which I conceived M. Bravais to have left in some doubt.

At Hammerfest, M. Bravais adopted as his point of obsertion an almost horizontal bank surrounding the small lake behind the town, together with a terrace, probably of transported matter, near by. On examining these objects I was at first of opinion that they represented the upper line, which was farther continued as a true line of erosion along the cliffs. I afterwards became convinced that they belong to a different system of markings, inconsistent in level with the true line of erosion as it exists at this place. That line is 84·73 feet above the highest tide-mark of the neighbouring shore, a point probably about six feet above the mean level of the sea.

(In what follows, I am to be understood as using, as a base in levelling operations, the same mark, as far as it could be ascertained, and as indicating distances in geographical miles.)

On Hoiöe or Hoy, an island much resembling the Bass in shape, four-and-a-half miles, a little to the south of west from Hammerfest, the same upper line is strongly marked at 85·29 feet, being nearly the same as the last-mentioned elevation.

About a mile to the west of Hammerfest, the upper line is strongly but roughly marked on the cliffy coast; and here I found the elevation to be 87·84. A little farther along the same line of coast, and a mile and a half from Hammerfest,

the elevation, at a very distinctly-marked place, was 89·49 feet, indicating a decided rise in this direction. Within Rypfiord, a bay a very little way onward, at a place one mile and a half of direct distance from Hammerfest, the elevation is 91·58, being nearly a rise of seven feet from the first point of observation.

At Saragamma, another place in Rypfiord, $2\frac{3}{4}$ miles from Hammerfest, the elevation is 96·69 feet, thus evidently observing a certain proportion of rise in this direction.

Passing round a promontory, along which, on both sides, the line is well marked, we found in Akkerfiord a broad alluvial marking in a green recess beside the discharge of a small river. This spot is $3\frac{1}{3}$ miles of direct distance from Hammerfest. The elevation of the terrace is 104·69 feet.

Hitherto no tolerably distinct trace of the lower line has appeared; but at length at Molstrand, about a mile onward from the last place, it becomes visible, as a rough impression on the precipitous coast, while a distinct terrace of blocks runs along for a short way at a still lower level. The elevation of the upper or grand line, as it may be called, here appeared at 106·11. The point which I assumed as that of the lower line is 43·75 feet, and the terrace of blocks 23·65.

From this point the upper line continues to be well marked, along the whole of the west coast of Qualoë, though for several miles mostly as an indentation in the soft face of the hill, there being only a few rough places where it appears as a terrace of erosion.

At Indre Sioholmen there is a green recess watered by a rill; and here, as might be expected, are some alluvial deposits. The lower line here appears as a green terrace at 44·97 feet; and the upper one in the same character at 114·32. There are two terraces in the alluvial formation at intermediate heights, namely about 97 and 106 feet.

The upper grand line is clearly traceable along the coast of Seiland, from a point opposite to Hoiöe; but I made no measurements there till we reached a place called Quisnaes, nearly opposite to Indre Sioholmen. Here the line is deeply impressed in the cliffs, at 106·87, being very nearly the same as at Molstrand, but decidedly below the terrace at the more

directly opposite place of Indre Sioholmen. I made two rough measurements with the mirror level, at parts of the coast of Qualöe further to the south, and found unquestionable proof of a continuous rise for the upper line, which is there very clearly marked, especially on the south coast.

Directly opposite to the southern angle of Qualöe, divided from it only by a narrow strait, is a promontory of the mainland called Beritsmol. The upper line is here presented as a broad flat terrace of rock, encumbered with blocks, but not so much as to prevent its being selected as a road by the reindeer, in their passage from one pasture to another. I took two measurements here, within half a mile of each other, and found a slight difference, the one being 129·22, and the other 130·66. These two points are not in the same line as the points of observation along Qualöe island; they cross that line of rise at a considerable angle. Turning a promontory to the eastward, we enter a small branch of the sea terminating in a valley, in which are situated the Kiopman's house of Qualsund, a chapel, and some lonely farms. The two lines here become broad green terraces, the upper of which is seen on both sides running for miles along, till it terminates in a morass near the head of the valley. This grand terrace, measured a mile along the valley, is 137 feet, shewing still a rise in the southerly direction. There is, however, something anomalous in the measurement of the lower line, for, while it appears at 53 feet as a line of erosion in the sound, it becomes a detrital terrace of only 44 feet on turning into the valley. Such at least is its elevation at the Kiopman's house, which is situated upon it.

The two terraces are well marked along the sounds skirting the east side of Qualöe, as far as the eye can see from Qualsund. At a place close to the entrance of Reppefiord, there is a recess or *sinus* in the line of the mountainous coast, where a little rill enters. The neighbouring hill-faces are covered with long irregular ridges of detrital matter, probably the relics of ancient moraines. In consequence, apparently, of this abundance of transported matter, the rivulet has formed a large delta, which projects like an immense spoil-bank from the hill-face into the sea. The upper

terrace is continued across this formation, as a broad flat plain of several acres in extent, and slightly ridged in front; shewing that the formation of the line has been an event subsequent to the subaqueous discharge and formation of the delta. It may be remarked that, 25 feet above this plain, is another of smaller extent, bearing curious curvilinear ridges in a direction from front to rear.

I continued my measurements along Varg Sund on both sides, and found a constant rise, though manifestly in a less rapid ratio. At a place a little east of Nœverfiord, the upper line passes distinctly across the almost perpendicular cliffs at 143 feet. At Rabastynaes, nearly opposite, I found, with the mirror level, the same line broadly marked at 144 feet, with a block of a different rock as large as a good-sized house reposing upon it. The great bold promontory called Quaenklubb (Plate III., *Upper View*) exhibits the lower line as a rough horizontal breach of the cliff, but the upper as a flat rocky floor of fifty paces broad, formed by a section of the almost vertical slaty strata, and 154 feet above the sea. In the adjacent green recess, the two lines form distinct indentations across the soft ground, the lower being here 57 feet. The face of Quaenklubb exhibits platforms at greater heights, namely, 176, 216, 302, and 318 feet, none of them of any great extent, and therefore dubious as indications of an ancient working of the sea, but remarkable for the burden which they bear of gneiss blocks and gravel, and other transported materials. On the platform at 302 feet, there is a block of gneiss, perfectly unworn, and measuring fully ten feet each way.

At Olderfiord in Seiland, a little farther along the sound, the upper line appears at 154 feet, besides two terraces in a green recess at 56 and 64 feet. At a point in the mainland opposite Storbeckarfiord, the lower line of erosion appeared at 64 feet, and the upper at 161. The latter is here a very rude flat, where not three yards are free of irregularities, produced by ridges of the strata, or loose blocks,—the cliff rising above it not less irregular,—the whole rendered still more rough by masses of moss, stumps of trees, and the living vegetation, from the wild flower to the birch; yet is the terrace nevertheless so far definite, that it has been

adopted at the line of a path marked by the feet of men and wild animals. The range of vertical space involved by the terrace floor and the cliff is from 20 to 25 feet.

The next station of observation was on the south side of the entrance to Leeristiord on the mainland. The upper terrace is there about 170 feet. It now becomes comparatively obscure, while the lower entirely escapes observation. In the next recess, called Komagfiord, the latter forms a green mound or terrace of fertile meadow-ground all the way round at from 57 to 64 feet. The upper line is very faint, and it is difficult to say in what manner it is produced. It was not till after many examinations and sightings of the one side of the valley from the other, that I determined its elevation at 179 feet. M. Bravais, who seems to have been under the same difficulty with it, states its elevation at a few feet less.

It will have been observed, that the rise of at least the upper terrace continues without any interruption throughout the whole of the twenty-five miles within which it is so distinct. From 85 feet at Hammerfest and Hoiöe, it has become 179, or 94 feet higher, at Komagfiord. The lower line, though more obscure, and less liable to exact measurement, also manifestly rises within a more limited space, namely, from about 44 at Molstrand to 64 at Komagfiord.

That the markings were made by the sea is, I presume, admitted on all hands. That the land involved in the case has made two angular movements, first, one subsequent to the time when the higher shelf was formed, and then another subsequent to the time when the lower line was impressed, seems also beyond question. These two positions are laid down by M. Bravais, and I believe they are not to be shaken. There remain, however, some interesting points of inquiry, as whether the movement has been regular, in what direction it has been made, and where was the axis of rest?

That the movement has been regular does, I think, appear from the measurements now presented; but this point can only be fully settled in connection with the next question, which regards the direction in which the movement has taken place. It will be observed, that the series of elevations from

Hammerfest to Beritsmol—that is, in a line south-south-east—is tolerably equable in proportion to the space passed over; but when we turn off into Varg Sund, in a line south-south-west, the rise is much slower. To give particulars: Between Hammerfest and Beritsmol, a space of $11\frac{1}{2}$ geographical miles, the rise is 46 feet; but from Beritsmol to Saraby, $9\frac{1}{4}$ miles, it is only 24 feet; while from this to Komagfiord, 9 miles more, it is 25 feet. If, however, we form a line nearly coincident with that of the first line of observation, as in the accompanying map, and, prolonging this into the mainland, raise upon it vertical lines touching the various positions in Varg Sund, we shall find that *equal spaces are passed through in this portion of the affected district within equal spaces of the rise.* It therefore appears that the rise is not slower in Varg Sund than in the sound between Qualöe and Seiland, but only the terrace is there not so coincident with the line of rise. The rise observably becomes accelerated as we pass on to Komagfiord, because the trend of the coast in that quarter gets more into a conformity with the line of rise. The heights taken on opposite coasts, moreover, as at Molstrand and Quisnaes, near Nœverfiord and at Rabastynaes, at Saraby and Olderfiord, correspond pretty well with this theory of the direction of the movement. In short, if a fair allowance be made for inaccuracy of maps, and the indeterminateness of the base line of the measurement (for a high water mark is in some places difficult to hit), it will appear that there is a remarkable approach to equability of rise throughout the whole of the space between Hammerfest and Komagfiord, the rate being pretty uniformly about 4 feet in a geographical mile.

M. Bravais regarded the possibility of the terraces having either risen at the one end or fallen at the other, so as to produce the slope; but he had not probably observed the two terraces which run along the coast to the southward, with little interruptions, for a space of about 180 miles, observing to all appearance, one uniform relation of heights, at 55 and 143 feet. I consider the two sloping terraces of the northern sounds, as a disturbed portion of the system represented by the two southern terraces. If this be a just view, the dis-

turbed land has moved on an axis of rest, rising at the one end and falling at the other. It has been a see-saw movement, the centre or point of which must be looked for at the place where the two inclined terraces are at the normal height of the system of which they presumably form a part. Keeping in view the upper one only, this place is in the line near the point of observation at Nœverfiord (see Map, Plate IV.), for the upper terrace is there 143 feet high, being the elevation of the upper line as measured at Tromsöe. From that place, the terrace falls 58 feet to the transverse line at Hoiöe and Hammerfest. How much farther it may have fallen in that direction, has not been ascertained. From the same central point it rises proportionately in the opposite direction.

Does the rise continue farther to the southward than the line of Komagfiord? I was at first of opinion, that it stopped here, instead of going on, as supposed by M. Bravais, to the embouchures of the Alten and Kaafiord rivers, because I found in Kortsfiord, the next opening to the southward of Komagfiord, what I believed to be the upper line, at nine or ten feet below its Komagfiord level. Hence it appeared to me as if that line had here attained a culmination point, and was beginning to descend towards the south. I have since, however, discovered the remarkable fact, that if the line of movement be prolonged till it comes abreast of the mouth of the Alten, the perpendicular line then raised upon it will pass through the whole range of terraces between that point and the mouth of the Kaafiord river, which are all of them about 220 feet high in front, but rise inland to an entire height of 239 feet; and this elevation will be just about what might be expected of the upper line prolonged to that point. (See Plate III., *Lower View, representing the alluvial terrace of Quaenvig, a good example of its kind.*) The uniformity of the elevation of these terraces over a range of 10 miles is in itself remarkable; their being traversed by the perpendicular line from the line of movement at the point where we might expect the elevation of the terraces to be attained (see Map, Plate IV.), is very striking. Finally, on considering the somewhat extraordinary character of these alluvial formations, I

became inclined rather to regard them as belonging to a disturbed than to a steady district. The objection from the terrace at a lower level in Kortsfiord may be allowed to give way, for there are so many anomalous markings in that valley, and in Komagfiord (to be presently adverted to), that a mistake may probably have happened. What adds in some degree to the probability of the Alten terraces being part of the district of disturbance, there are similar sandy formations connected with other rivers at Melsvig and Talvig; and these, being five or six miles less advanced upon the presumed line of movement, are proportionately lower. If we assume that the district of disturbance extends thus far, the vertical movement connected with that disturbance at Alten must be regarded as equal to the difference between 143 and 239, or 96 feet. Does the movement extend farther southward? We should have to answer in the negative if M. Bravais is right in saying that the great Alten terrace goes for four or five leagues along the valley without change of height; but this point may be worthy of future inquiry.

M. Bravais indicated the existence of a faint intermediate line, which he observed both at Hammerfest and Alten, and which he conceived to imply an intermediate movement. But the fact is, there are, at many stations throughout the disturbed district, terraces over and above, though mixed up with, the noted two which are here discussed. At Hammerfest, besides the intermediate line alluded to by M. Bravais, which is formed by a grand terrace of blocks fallen from the schistous mountain behind the town, there is, on a hill-face near by, a series of shingle terraces, scantily covered with vegetation, and precisely resembling shingle beaches of the present day, at 87, 123, and 144 feet. There is also a ring terrace of transported matter, topped with water-laid sand, round the Lake of Hammerfest, at 97 feet above the sea. Here, it will be observed, are traces of the sea at not less than three elevations superior to the higher of the two lines. In Rypfiord and at Indre Sioholmen there are also terraces above the higher line. Such is likewise the case at Qualsund. In Komagfiord, at the entrance of its little river, there is a series of terraces both below and above the lower

line, besides a broad flat terrace of soft materials on the hill-face at 161 feet, being 18 below the upper line. In Kortsfiord there are similar objects, particularly the terrace already alluded to at 169 feet, and one connected with a mountain streamlet at 241. The distinctest markings of this kind, however, are seen on the faces of the Alten and Kaafiord formations. At Bossikop, Quaenvig (see Plate III., *Lower View*), and Kaafiord, there is one of marked importance at between 80 and 90 feet, being probably that which M. Bravais set down as the lower line in that district. It appears as a cincture round the singular sandy promontory of Oskarnaes, at a few feet lower; which is what might be expected, as that is a point some way advanced on the assumed line of dip. There are, besides, however, at Quaenvig and Kaafiord, markings equally or even more decided, at 52, 123, 144, and 167 feet, indicating no fewer than three movements between the dates of the upper and lower lines, and at least one subsequent to that of the lower. To establish connections among these markings, would obviously require no small amount of additional observation.

The general fact may now be considered as tolerably certain, that there is a district in Finmark, of 40 geographical miles in extent, which has sunk 58 feet at one extremity, and risen 96 at the other. Its line of dip and of rise is pretty well ascertained. It is not greatly different from that of the magnetic meridian for the district, which is about 11° west of north. The movement has been surprisingly equable over relative proportions of the space. A shift of the relative level, after the manner of the Alten and Hammerfest terraces, is, however, exceptional, for there is a much larger district to the south, which has evidently been involved in this process of shift at the same time, but where that shift has taken place without being attended with a change of the plane originally observed by the land. In the central and southern districts of Norway, there are other ancient sea-markings, which appear to preserve horizontality, and even awaken the surmise, that they coincide with similar levels in other countries.

There is, however, a large tract in the south and east of

Scandinavia which is ascertained to be undergoing an elevatory movement, even at the present day. I was able to visit the celebrated stone at Löfsgrund, near Gefle, on the Gulf of Bothnia, which has been marked with the height of the water at various periods; lastly, by Sir Charles Lyell in 1834. I found his mark 2 feet 7 inches below that of 1731; and the sea, on the day of my visit (2d September), was about 6 inches below Sir Charles's mark, or rather more than 3 feet below that made 118 years before. It occurred to me as unfortunate to have selected for this kind of test a loose block lying near the shore; for we cannot exclude the suspicion, that the ice may carry it a little way up the beach every winter. Nevertheless, as there are other marks presenting similar results, where no such liability to fallacy exists, the probability is, that no movement has actually taken place. Two days afterwards, I visited the mark made by Flumen upon the cliff of Grasöe, near Oregrund, in 1820. The sea was so calm as not to wet more than an inch of the cliff above its ordinary level of the day; and the seamen informed me, that the water was at a very fair average for the season. I found the surface of the water 11 inches below Flumen's mark, which had been made only nine days later in the year. Thus, if the sea at the two periods was in similar circumstances, or at its mean level for the season, there appeared to have been a rise of the land in this district to the extent of 11 inches in twenty-eight years.

A Conjecture as to the Forces which produce the Tails of Comets. By William John Macquorn Rankine, Esq., C.E. Communicated by the Author.

The immense velocity with which the tails of comets, on the approach of those bodies to their perihelia, are projected in a direction opposite to that of the sun, has always been held to indicate that the particles of those nebulous envelopes are acted upon by some powerful force directed from the sun. Various hypotheses have been proposed as to the na-

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These banks, for several miles from the embrochure of the stream, are composed of terraces of clayey alluvium, rising above each other to the height of several hundred feet. In some instances, I succeeded in ascertaining that these were of corresponding heights on the different sides of the river. Some of them persevere for several miles along the valley at one uniform height. I therefore considered them as roughly indicative of stages or pauses in the change of the relative level of sea and land. Taking as a basis the surface of the sea, which is here at its mean level, I found, by careful measure-

ment with the level and the staff, that two of the most distinct and persistent of these terraces were respectively of these heights, namely, 77 and 98 feet; taking in both instances that point in the sectional outline of the terrace, where the moderate inclination of its surface gives place to a new rise. A very distinct portion of this latter terrace runs along under a country-house called Nystad, and towards one called Rudd House.

The valleys of those affluents of the Glommen River, which are crossed on the road from Christiania to Trondheim, are full of alluvial terraces of various materials. That of the Nytte River presents terraces of sand; that of the Leer River (a different river from the Lir above mentioned) affords terraces of clay ; and hence, no doubt, the name given to the stream. The appearance of these terraces, broken into short spaces by side streams, and often having farmsteads perched on the detached pieces, while the banks in front descend at a deep inclination to the bottom of the valley, produces scenery of a peculiar and striking kind. The pass from this valley to the next, in which runs the river issuing from the Midsen Lake, is a broad flat space composed of a bed of water-worn gravel, with pieces as large as a man's head ; and this flat is several hundred feet above the level of the sea.

The valley, containing the river issuing from the Midsen Lake, is several miles broad, between hills of no great elevation ; yet it is filled from side to side with a formation, at least topped with pure sand, generally flat, and extending with a slight rise up to the lower extremity of the lake, which

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it embraces in a beautiful curve, rising in a steep bank about 240 feet above its waters. The outlet of the lake is through a deep trench in this formation. In the neighbourhood of the lake, the sandy plain rises towards the hills on each side, at a gentle inclination, and with a remarkably equable surface, like a sea-beach. What adds not a little to this resemblance is a fringe of gravel at a greater inclination, abutting against the hill-side. Taking the height of the Midsen Lake on the day of observation at 420 feet above the sea, the utmost elevation of this ancient sea-margin above the present sea-level appears to be about 656 feet. In the inner valley or trench, cut by the river, there are minor terraces, at respectively 522, 533, and 598 feet above the sea. A few miles down the valley, at the Trygstad post-station, a great terrace is seen passing for several miles at one level along the hill-side, rendered the more conspicuous by the bright line of green formed by its grassy turf, in contrast with the dark hue of the woods which rise immediately from it to the very summits of the hills. With the spirit-level, I found the line of this terrace to be about the same height with Trygstad station, which is given as 590 Rhenish feet above the sea, in Professor Keilhau's Goea Norvegica. As this is an unusually distinct example of the ancient beach, it is very

desirable that its elevation were more exactly ascertained. Meanwhile, we may be tolerably satisfied, when we allow for the difference between Rhenish and English measure, that it is nearly, if not quite, identical in height with the terrace just spoken of as 598 feet. It may also be remarked, that the Scandinavian geologists report upon an ancient beach of 597 feet at Lake Oyeren, a lower portion of this group of waters, distant only a few miles from Trygstad. It might be worth while to inquire if any connection can be established between these terraces.

These ancient sea-markings will be the less liable to challenge on the part of my present audience, when I remind them of the conclusion arrived at several years ago by the geologists of Scandinavia, that there are proofs, in terraces and shell-deposits, of that peninsula having been upraised from 600 to 700 feet, at a period immediately preceding the a

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historical era. There are not wanting, however, evidences of a similar nature, that the relative level of sea and land has, in Scandinavia, undergone a much greater change. The valley of the Rauma, which opens upon the west coast, and that of the Logan, an affluent of the Glommen, which pours itself into the Baltic, meet in a trough of country in the Dovre field, the summit of which is occupied by the Ldsso-verks vand, 2045 feet above the sea. By an extraordinary natural arrangement, the lake emits the Rauma at one end and the Logan at the other; so that a portion of Norway is completely enclosed by natural water. The valley of the Logan, for several miles down, contains great masses of pure sand, in the form of terraces and isolated mounts. On one of the latter, Dovre Church is situated, at an elevation of 1543 feet. In this portion of the valley, there is a terrace unlike the rest, in as far as it is a narrow ledge of detrital matter, running continuously along the hill-side for fully 14 miles, however much more, while the terraces resting on the skirts of the hills lower down are great projecting masses, seldom extending far on one level. This remarkable terrace is most conspicuous on the right or south-west side of the valley. It begins on that side at Oue, between the Hougen and Tofte post-stations. It is there seen truncating the prominent ancient delta of a side stream, called, in Professor Munch's map, the Jondal's Elv, several hundred feet above the bottom of the valley. As we ascend the valley, it becomes nearer to our eye; but this is only because we rise to it, for, when examined with a correct instrument from its own elevation on the opposite side, it is proved to be for a great way truly horizontal. On the left or north-east side of the valley, the corresponding mark is a line composed of slight projecting banks of water-laid sand. Though not continuous, this line is sufficient to have determined that of a long mountain-path connecting a series of farms. Beyond Lie post-station, the

road to Molde passes along it, and it here affords positions for a close series of hamlets, which make a conspicuous appearance in the map above cited. I believe it is nearly, if not exactly, of the same elevation with the little hof, called

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Dombaas, of which the height is given by Prof. Naumann as 2162 (English) feet. In its relation to the lakes in the summit between the two valleys, it precisely resembles the lowest of the Inverness-shire parallel roads, as exemplified in Glen Spean, where advancing to the basin of Loch Laggan, between the Spean and Spey valleys. The terrace in every other respect bears a strong resemblance to the Inverness-shire roads; while in some important respects, as already noted, it differs from other terraces. I should much desire to see it obtain the attention of local observers, by whom its internal constitution and other features could be more particularly ascertained. Meanwhile, it is not unworthy of remark, that on a neighbouring portion of the plateau of the Dovre field, between two and three thousand feet above the sea, there are peat mosses containing remains of much larger trees than now grow in the district, the vegetation of which does not ascend above a dwarf birch. If the terrace were at one time upon the level of the sea, this plateau would of course enjoy a climate equal to that of districts of a few hundred feet of elevation, and it might then be well able to raise such pieces of timber as now lie ruined in the mosses.

The city of Trondhiem lies at the opening of the valley of the Nid, with high grounds on the east side, and a bold cliffy hill overlooking the sea on the west. Close to the town, and along the valley for several miles, there are terraces of clayey material, none of which persevere for a great way. From indeterminateness of form, and partly of level also, it is impossible to state their elevations with great distinctness ; but I may mention, for the sake of general description, that, on sighting them with the telescope-level across the country, they exhibited lines, more or less definite, at about 60, 111, 145, 253, and 435 feet. The most interesting object of the kind is a terrace of erosion, on the face of the cliffy hill to the west of the city. This is an extraordinary and most impressive example. It extends for miles along the face of the hill, at one uniform elevation, which I ascertained with the level and staff to be 522 feet above the

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sea. Seen from the opposite side of the valley, or from the streets of Trondheim, it appears as a dark band across the hill-face. On near inspection, we find a deep cut into the

almost horizontally disposed slate-rocks, with a ledge, flat though rough, at some places as much as twenty paces broad, while overhead rises a cliff more or less bold, formed of the angular edges of the broken strata, with here and there a modern talus descending upon the terrace. Not the least doubt can exist, that it is the effect of the working of the sea, when this part of the hill was on a level with the waves. On the opposite coasts of the Trondheim fiord there are marks of a similar terrace at apparently about the same elevation. The drawing here exhibited presents the appearance of the terrace above the city of Trondheim, at a place where its floor is well defined and flat, and the cliff nearly vertical, and certainly not less than forty feet high. Directing our eyes to the southward, we here see a hill about a mile off, called Sverrosborg, because King Sverro, a distinguished Norwegian monarch of the twelfth century, had a fort upon the top of it. This top is composed of a mass of bare rock about thirty feet high, starting up out of the green-sided hill. The terrace of erosion is marked all round under the mass of bare rock, producing a curious and quaint appearance. The sea has manifestly worn out this terrace at the time when it produced the line of erosion on the neighbouring hill-face, for it is precisely of the same height. Some of the neighbouring grounds come to about the same level, as if produced by a contemporaneous silting-up of these spaces to the surface of the sea.

Connected with this terrace of erosion there are some remarkable alluvial terraces in the interior of the country. A few miles to the south-east of Trondheim, the road leaves the Nid valley, and passes into that of the Gula, a powerful river which discharges itself into a neighbouring branch of the fiord. The country over which the road passes between the two valleys, is a spacious moor, composed of detrital matter, and very flat. Its general elevation is about the same height with the great terrace of erosion. When we advance into the Gula valley near the post-station of Oust,

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we see a terrace commencing along the east side of the valley, and persevering at one height for a considerable way, being just about the same elevation with the aforesaid moor. This terrace is clearly of the same kind with that in the Logan valley, not a product of fluviatile deposits, as so many terraces are, but of the long-continued washing of the sea against a mountain-side. Descending into the Gula valley, we find vast alluvial deposits, generally of a muddy character, and sometimes terrassiform. Their composition changes as we advance to a fine sand; and this again begins to shew a gravelly admixture, the light materials having, as usual, been carried farther than those of a heavier nature. Near the Meelhuus post-station, which is 123 feet above the sea, there is a sand terrace fully 200 feet high, and from the face of which the material rises in a cloud

with every gust of wind. The comparatively low terraces, resting in huge masses on the skirts of the hills, continue for several miles to be very conspicuous, while the higher line on the hill-faces is no longer traceable. At length, between the Leer and Vollan post-stations, and about 25 miles from Trondheim, a highly-remarkable alluvial formation is observed upon the left or west side of the valley. It has a surface perfectly flat, and perhaps an English mile broad, abutting against the hills behind, and in front descending in a steep grassy bank to the river's brink. It extends for miles along the valley, always preserving one elevation, while a terrace of the same height, but less persevering, is seen on the opposite side. The termination in the downward direction of the valley is abrupt, as if the terrace had been broken down at a certain point by the retiring sea ; and here there are seen, on the face of the bank below, five several minor terraces, extending only a short way. The accompanying sketch will convey a more lively, though still imperfect, idea of these objects. Iam unable to speak with precision of the height of this grand alluvial terrace ; but, from my observation of its elevation above the Vollan station, which is set down as 310 feet by Mr Keilhau, I deem it not unlikely that it will prove, on examination, to be coincident with the aforesaid line at Oust, and the terrace of erosion at

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Trondhiem. This is the more likely, from what may be observed at Soknaes, the next post-station in the valley. There is here a wide space formed by the junction of a branch valley. The whole space within sight might be described as a nest of alluvial terraces, reaching to a considerable height above the two rivers. At one spot, near Soknaes, aS Many as six are seen rising above each other, the inn being placed on a promontory formed by the fourth of the series. A connection between this group of terraces and that at Vollan is obscurely traceable along the valley. By M. Von Buch, the elevation of the Soknaes station is set down at 487 feet ; and hence, I presume, that the sixth or highest terrace at that place may be about the same elevation with the Trondheim line of erosion, or 522 feet. It is desirable that a careful examination of the whole of the Gula markings should be made, and their levels ascertained, in order to ascertain how far they observe uniformity, and if any of them be truly identical in elevation with the Trondheim terrace of erosion, as here surmised from observations which I am sorry to find so much more vague than was to be desired. On the Sokna, the branch of the Gula here spoken of, there is a similar system of alluvial terraces, on one of which the church of Soknadalen and post-station of Hof are situated. It may be remarked, however, that such terraces, though evidencing a shift of the relative level of sea and land, are not always exact marks of the point at which the sea and land formerly met. Where found sloping in the line of the val-

ley, as is the case with several at Hof, they may be regarded as only the ancient haughs of the river before the withdrawal of the sea (so to speak) allowed it to cut down its alluvial deposit, and seek a lower channel. Where, on the other hand, an alluvial terrace is of the character of that at Vollan, not only broad and flat, but extending a long way upon one level, experience teaches me to expect such relations of measurement as indicate its being the true mark of an ancient line of coast. Among the Soknadalen terraces, I find that I have noted that on which the post-station and church are situated as alone answering the requirements of an ancient sea-level, making the additional remark, that the

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exact site of Hof is probably a few feet lower, as not being at the highest point of the terrace. By M. Von Buch the elevation of Hof is given as 945 Paris feet above the sea; by another observer it is placed somewhat lower. The mean, given by Professor Keilhau, is 960 Rhenish feet. It appears probable, that the former relative position of the sea is, in this instance, elevated between 990 and 1000 English feet.
I have now to lead attention to the shores of the provinces of Nordlands and Finmark, only previously remarking, that in the intermediate coast there are no terraces of any kind visible from the open sea, there being, in reality, scarcely any detrital formations there, while the rocks are so smoothed by glacial action, as to have afforded little inlet to the erosive power of the waves. It is not till we reach the Island of Hindée, one of the Lofoden group, that any such markings are presented. In Raft Sund, on the south-west side of that island, about latitude 68° 20', two faint terraces of erosion are traceable. They are also seen on both sides of the strait between the island and the mainland. At Trondinaes, the northern point of the island, where there is a recess of comparatively soft ground in the iron-bound coast, these two lines are more conspicuous, forming indentations in the grassy slopes; while, in the rocky cliffs, they appear as strongly-marked terraces of erosion. A rough little island, called Magie, at this place, is cinctured with these terraces of erosion, exactly like the hill of Sverrosborg, but in a more marked manner, for here the waves of the ancient sea have had to deal with strata of unequal hardness ; therefore, some masses are left starting up in sharp ridges and rude columns above the general floor of the terrace, which is nevertheless sufficiently well-defined. In all circumstances, the two lines seem to preserve their respective heights undeviatingly, the one being apparently about 50 feet high, and the second 100 feet higher.
In an inlet of the Island of Anderide, a few miles from Hindée, I observed three terraces at a place called Ibbestad, all apparently under 100 feet, and therefore, presumably, a different system from those hitherto noticed.
Farther north, after passing the great inlet of Balsfiord, we

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find in Trom Sund, the two former terraces resumed. I have been informed, however, by a gentleman of Tromsje, who has given some attention to the terraces of the district, that there are several distinctly traceable in Balsfiord, one of them at the height of perhaps 400 feet above the sea.

In Trom Sund, the faces of the hills are soft and green, and the two terraces appear as slight, but distinct indentations in the grassy slope, never failing to preserve to all appearance, one relation of levels. Itis remarkable, that, while clear and conspicuous on both sides of this narrow sound, they are scarcely to be traced on either side of the interjected island of Tromsée. On the north-west side of the sound, behind the island, there is a faint appearance of a third terrace upwards of 100 feet above the second. Of the two distinct terraces I took a measurement with the level and staff, and found them to be respectively 57 and 143 feet above the highest tide-mark. Another observer, M. Siljestrom, has given measurements of them slightly different, namely, 56 and 149 feet, and has added the elevation of a third, which I did not succeed in seeing, at 220 feet.

In the range of sounds through which the post-steamer passes, in the sixty-ninth degree of latitude, I observed the two lines well marked on the green skirts of the hills, with scarcely any interruption. The continuity from island to island is very remarkable. Sometimes there is an escarpment or a line of exposed rock, to render the ancient sea-mark the more distinguishable. All along there seems to be not the slightest departure from one set of levels.

In recesses, where perhaps little rills have brought down some detritus, not only these two terraces are marked, but several intermediate ones besides. Ata promontory of soft matter, called Skatoren, forming the eastern extremity of the island of Ringvatsée, there are at least four terraces below the higher of the two already so often alluded to, besides some minute and less distinct markings. On the island of Vorterée, at the south point, which consists of a narrow lofty rock, there is an object of an instructive character, namely, a series of terraces on one side, with a series of greater elevation on the other, shewing how it may depend

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on local circumstances, as currents and perhaps prevailing winds, that any such impressions are to be made upon a coast, while the relative level is in the course of being changed.

The farthest north point to which I traced the remarkable couple of terraces is Mour Sund, fully ten hours' sail north

of Tromsée. The mountains then begin to be rough with debris, so as perhaps to have presented an unsuitable surface for such markings. M. Keilhau appears to have found the lower of the two still farther along to the north-east, namely, in Langfiord, one of the branches of the Altenfiord. The terrace which he observed in that place is set down by him at 523 feet above the sea. The gentleman who told me of the terraces in Balsfiord, assured me of there being similar objects in Lyngenfiord, a great inlet which receives several considerable streams. A careful examination of these recesses would probably afford a rich harvest of results, and help materially to solve the problems connected with this subject.

We now approach a portion of the coast, presenting a group of terraces which has already attained some celebrity. The district in question may be said to extend from the Altenfiord, with its branch Kaafiord, into the strait called Varg Sund, which is formed by the mainland on the one side, and the Island of Seiland on the other; being afterwards prolonged into the two sounds surrounding the Island of Qualée. Altogether it is a range of estuaries and straits extending about fifty miles in a direction generally north and south, and mostly comprised in the 70th degree of latitude. This portion of the Norwegian coast was examined in 1839, by M. Bravais of the French Scientific Expedition of the North ; and the facts pointed out by him were briefly these :—

At the mouth of the river Alten, there is a terrace of sand, 223 feet above the sea, and this extends up the river, always on the same level, till, at a village five or six Jeagues in the interior, it is only about 91 feet above the general level of the district. At the mouth of the smaller stream, commonly called the Kaafiord Elv, a few miles from the mouth of the Alten, there is a similar sandy terrace at the same elevation

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above the sea, besides a narrow shelf, “ like the towing-path of a canal,’ about 90 feet above the sea.

Proceeding in a northerly direction, M. Bravais found at Krognaes and Talvig an alluvial terrace at 185:5, and another whose mean height was 80°5 ; and these he considered as representing the two others, though at lower levels. Advancing in the same direction, he found at Komagfiord two lines of erosion on the faces of the mountains, respectively 169°6 and 67:3 feet above the sea.

Still further advancing, he found the same two lines on the precipices of Quaenklubb, at 162°3 and 60 feet ; at a place on the islands of Seiland and Qualée at 139-3 and 54 feet. Finally, at Hammerfest, the two lines appeared at respectively 92°3 and 46 feet. Thus it appeared that there was a constant decline in the elevation of these markings from south to north. M. Bravais likewise observed some less distinct tracings of the same kind,—a dark-coloured band on Kongshavensfield, near Bossikop, at 128 feet ; and one further on,

upon the same side of the fiord, at Sortbierg, at 81 feet; a line of erosion between Storvignaes and Krognaes, at 126 feet, and one at Talvig of 141 feet. He regarded these as indications of an intermediate line which had failed to be expressed throughout the intermediate space, but which reappeared at Hammerfest in a terrace of about 69 feet.

It may be remarked that M. Bravais used a barometer for his measurements, adopting usually the mean of several observations, and that he took as his basis a point 0™:6 above the line formed by the sea-weed on the rocks, having found that line 64 centimetres above mean height of the sea.

M. Bravais inferred that there had been at least two distinct angular movements of elevation in the region comprehended by the terraces, the first being measurable by the difference of heights between the upper and lower terrace, and the second by the height of the lower terrace at various points above the sea. The following table indicates the amount of the first elevation :—-

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80 Robert Chambers, Esq., on Changes of the

Points of Observation, 1. 2. oe 4, a 6.
Upper Line, ° 223 185°5 169°6 162°3 139°3 92:3
Lower Line, F OP ASU bea Ore = 100: 54° 46°
Amount of Ist Elevation, 132 105°0 102°3 102°3 85'3 46:3

He remarked, however, that the intermediate terrace considerably alters the relative amount of the earlier and later elevations along the coast, reducing the first or most ancient to about 24 feet, making the second or intermediate movement of 22 feet, and leaving the third or most recent of 46 feet, and therefore considerably greater than the other two.

In a work published by me on Ancient Sea-Margins, 1 expressed some doubts as to the alleged inclination of the Finmark terraces, being partly led thereto by the discovery, in other parts of the earth, of uniform levels for such markings ; while it likewise appeared to me that, for perfect proof of M. Bravais's positions, we should have required either evidence of greater continuity in the appearances, or measurements taken at a greater number of points. I deemed it not unlikely that the fragments of terrace which he saw at different places might be, not representative of two great lines, as he supposed, but representative of a number of lines nearly if not quite equal to the number of the points of observation. I was therefore glad when I was able to pay a visit to Finmark, with a view to making a rigid personal examination of the terraces, and with the means of measuring their elevations more accurately than had yet been done. The result I am now to bring before this Society.

The general fact of the existence of two continuous lines of erosion on the rocky coast between Kortsfiord and Hammerfest I found to be true. They appear as part of the same system of terraces with those seen farther south, or as a prolongation of them; but, unlike those terraces, they do not observe a level, for the upper line is at one end not much

less than a hundred feet higher than it is at the other. It is about the middle that they bear the best resemblance to the couple of terraces in Trom Sund and elsewhere. The resemblance is chiefly in likeness of elevation. As to the material, there is a difference throughout a great part of the

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space ; for while the terraces towards the south are chiefly indentations in soft matter, those of Varg Sund are chiefly sections made in the rocky cliffs,—true terraces of erosion. In these northern terraces, however, the lines are in some places continued from a rocky hill-face to a soft grassy slope, changing from a cut in the rocks to a mere impression on the detrital surface, without any change in their direction or inclination. The appearance of two such markings along about twenty-five miles of coast is calculated to arrest the attention of every intelligent stranger ; and even the natives, who are chiefly Laplanders, have not failed to remark them, and to attribute them to the agency of the sea, though not doubting that the sea has simply retired from two several heights at which it had formerly stood. No one on the spot seems to have ever thought it worth while to inquire whether they observe one level, or at what height they stand in any place above the sea.

When I speak of the two lines as distinct, 1 mean that they are so strongly marked as to be visible from a considerable distance. For example, a person Standing on one side of Varg Sund, though it is fully three miles broad, can, in tolerably clear weather, easily see the lines passing along the opposite coast. (See Plate III., Upper View.) When narrowly inspected, those designated as terraces of erosion are found to be produced by a true mechanical incision of the rock, sometimes leaving a ledge with a precipitous cliff overhanging it, sometimes consisting only of a rough groove across the mountain-side, without any distinct ledge being left,—sometimes, again, under a form intermediate to these two in all imaginable degrees. Very frequently, when wishing to examine a portion of the line, though it may at a little distance have appeared sufficiently palpable, it is found on near inspection to be obscure and indeterminate, the eye in that case not taking in at once a sufficient amount of the line to produce a distinct impression, and the immediate objects appearing rough and confused. In other places a well-defined section is offered for inspection. For example, at one part of the prominent rock called Quaenklubb (see above view), the upper line is a terrace thirty paces broad,

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a flooring flat and smooth, produced by a power which has been sufficiently strong to cut sharply through the hard slaty strata, and leave scarcely any inequalities. At the same place, in strong contrast with this marking, the lower line shews, on near inspection, only a shattering of the cliff, and a wearing of it out in vertical hollows; so that it would be impossible to say, within eight or ten feet, what is the height of that line. At a place on the south side of Qualée island, I found appearances respecting which the following entry was made in my note-book :—** Nothing could well be more perfect than the /edge formed by this terrace, there being only such irregularities as were unavoidable from the various hardness of the strata; some having been so very hard as to leave a slight ridge above the line, while, in other instances, a mass was left like a gross short column standing up as a monument of what it had been originally connected with. One of these surviving masses looked much like the ruins of some old castle." Ata place on the mainland, opposite to the above, I found a similar ledge, but with an irregular row of short columnar masses in front, somewhat like the obelisks designed to support a chain along the skirts of an artificial terrace, while in a vacant space arose a rough rock, round the top of which the sea had cut a circular flat, causing the upper prominence to appear like a human head rising above a broad pair of shoulders. (The picture here exhibited of the line of erosion at Trondheim gives a good idea of the section of a terrace which has a flat, well-defined floor and cliff rising above, as well as of an isolated mass cinctured by a terrace, like the object last spoken of.)

It may be remarked that, according to M. Bravais, probably reporting the observations of Professor Keilhau, "the mountains of Altenfiord and of all this part of the coast belong to the group of metamorphic rocks; but the nature of the rock differs widely, since calcareous beds are found at Storvignaes, and at Talvig, between Kortsnaes and Skillifiord, amphibolic rocks on the island of Seiland and near Hammerfest ; while diallage, quartzose sandstones, and argillaceous schists, are not rare.' M. Bravais adds, that he was not able to judge of the influence of these rocks on the

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different phenomena of the neighbourhood. I may further remark that the only general feature that seems likely to have told in making the mountains along the sea susceptible of such impressions is the fact of its being an inland sea. The direction of the various sounds and estuaries can scarcely be supposed influential, as, in fact, the markings are made upon coasts in a great variety of directions.

With the assistance of Mr Paddison, civil engineer, who was so kind as to associate himself with me in my examination of these terraces, I executed a series of accurate level-

lings at about eighteen points along the space between Hammerfest and Kortsfiord, and completely convinced myself of the reality of the inclination, which I conceived M. Bravais to have left in some doubt.

At Hammerfest, M. Bravais adopted as his point of obsertion an almost horizontal bank surrounding the small lake behind the town, together with a terrace, probably of transported matter, near by. On examining these objects I was at first of opinion that they represented the upper line, which was farther continued as a true line of erosion along the cliffs. I afterwards became convinced that they belong to a different system of markings, inconsistent in level with the true line of erosion as it exists at this place. That line is 84°73 feet above the highest tide-mark of the neighbouring shore, a point probably about six feet above the mean level of the sea.

(In what follows, Iam to be understood as using, as a base in levelling operations, the same mark, as far as it could be ascertained, and as indicating distances in geographical miles.)

On Hoiée or Hoy, an island much resembling the Bass in shape, four-and-a-half miles, a little to the south of west from Hammerfest, the same upper line is strongly marked at 85-29 feet, being nearly the same as the last-mentioned elevation.

About a mile to the west of Hammerfest, the upper line is strongly but roughly marked on the cliffy coast ; and here I found the elevation to be 87:84. A little farther along the same line of coast, and a mile and a half from Hammerfest,

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the elevation, at a very distinctly-marked place, was 89°49 feet, indicating a decided rise in this direction. Within Rypfiord, a bay a very little way onward, at a place one mile and a half of direct distance from Hammerfest, the elevation is 91-58, being nearly a rise of seven feet from the first point of observation.

At Saragamma, another place in Rypfiord, 23 miles from Hammerfest, the elevation is 96°69 feet, thus evidently observing a certain proportion of rise in this direction.

Passing round a promontory, along which, on both sides, the line is well marked, we found in Akkerfiord a broad alluvial marking in a green recess beside the discharge of a small river. This spot is 33 miles of direct distance from Hammerfest. The elevation of the terrace is 104-69 feet.

Hitherto no tolerably distinct trace of the lower line has appeared ; but at length at Molstrand, about a mile onward from the last place, it becomes visible, as a rough impression on the precipitous coast, while a distinct terrace of blocks runs along for a short way ata still lower level. The elevation of the upper or grand line, as it may be called, here appeared at 106:11. The point which I assumed as that of the lower line is 43°75 feet, and the terrace of blocks 23°65.

From this point the upper line continues to be well marked, along the whole of the west coast of Qualoé, though for several miles mostly as an indentation in the soft face of the hill, there being only a few rough places where it appears as a terrace of erosion.
At Indre Sioholmen there is a green recess watered by a rill; and here, as might be expected, are some alluvial deposits. The lower line here appears as a green terrace at 44:97 feet; and the upper one in the same character at 114-32. There are two terraces in the alluvial formation at intermediate heights, namely about 97 and 106 feet.
The upper grand line is clearly traceable along the coast of Seiland, from a point opposite to Hoide; but I made no measurements there till we reached a place called Quisnaes, nearly opposite to Indre Sioholmen. Here the line is deeply impressed in the cliffs, at 106°87, being very nearly the same as at Molstrand, but decidedly below the terrace at the more

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directly opposite place of Indre Sioholmen. I made two rough measurements with the mirror level, at parts of the coast of Qualée further to the south, and found unquestionable proof of a continuous rise for the upper line, which is there very clearly marked, especially on the south coast.
Directly opposite to the southern angle of Qualse, divided from it only by a narrow strait, is a promontory of the mainland called Beritsmol. The upper line is here presented as a broad flat terrace of rock, encumbered with blocks, but not so much as to prevent its being selected as a road by the reindeer, in their passage from one pasture to another. I took two measurements here, within half a mile of each other, and found a slight difference, the one being 129-22, and the other 130-66. These two points are not in the same line as the points of observation along Qualoe island ; they cross that line of rise at a considerable angle. Turning a promontory to the eastward, we enter a small branch of the sea terminating in a valley, in which are situated the Kiopman's house of Qualsund, a chapel, and some lonely farms. The two lines here become broad green terraces, the upper of which is seen on both sides running for miles along, till it terminates in a morass near the head of the valley. This grand terrace, measured a mile along the valley, is 137 feet, shewing still a rise in the southerly direction. There is, however, something anomalous in the measurement of the lower line, for, while it appears at 53 feet as a line of erosion in the sound, it becomes a detrital terrace of only 44 feet on turning into the valley. Such at least is its elevation at the Kiopman's house, which is situated upon it.
The two terraces are well marked along the sounds skirting the east side of Qualée, as far as the eye can see from Qualsund. At a place close to the entrance of Reppefiord, there is a recess or sinus inthe line of the mountainous coast, where a little rill enters. The neighbouring hill-faces

are covered with long irregular ridges of detrital matter, probably the relics of ancient moraines. In consequence, apparently, of this abundance of transported matter, the rivulet has formed a large delta, which projects like an immense spoil-bank from the hill-face into the sea. The upper

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terrace is continued across this formation, as a broad fat plain of several acres in extent, and slightly ridged in front ; shewing that the formation of the line has been an event subsequent to the subaqueous discharge and formation of the delta. It may be remarked that, 25 feet above this plain, is another of smaller extent, bearing curious curvilinear ridges in a direction from front to rear.

I continued my measurements along Varg Sund on both sides, and found a constant rise, though manifestly in a less rapid ratio. Ata placea little east of Neeverfiord, the upper line passes distinctly across the almost perpendicular cliffs at 143 feet. At Rabastynaes, nearly opposite, I found, with the mirror level, the same line broadly marked at 144 feet, with a block of a different rock as large as a good-sized house reposing upon it. The great bold promontory called Quaenklubb (Plate III., Upper View) exhibits the lower line as a rough horizontal breach of the cliff, but the upper as a flat rocky floor of fifty paces broad, formed by a section of the almost vertical slaty strata, and 154 feet above the sea. In the adjacent green recess, the two lines form distinct indentations across the soft ground, the lower being here 57 feet. The face of Quaenklubb exhibits platforms at greater heights, namely, 176, 216, 302, and 318 feet, none of them of any great extent, and therefore dubious as indications of an ancient working of the sea, but remarkable for the burden which they bear of gneiss blocks and gravel, and other transported materials. On the platform at 302 feet, there is a block of gneiss, perfectly unworn, and measuring fully ten feet each way.

At Olderfiord in Seiland, a little farther along the sound, the upper line appears at 154 feet, besides two terraces in a green recess at 56 and 64 feet. Ata point in the mainland opposite Storbeckarfiord, the lower line of erosion appeared at 64 feet, and the upper at 161. The latter is here a very rude flat, where not three yards are free of irregularities, produced by ridges of the strata, or loose blocks,—the cliff rising above it not less irregular,—the whole rendered still more rough by masses of moss, stumps of trees, and the living vegetation, from the wild flower to the birch; yet is the terrace nevertheless so far definite, that it has been

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adopted at the line of a path marked by the feet of men and

wild animals. The range of vertical space involved by the terrace floor and the cliff is from 20 to 25 feet.

The next station of observation was on the south side of the entrance to Leeristiord on the mainland. The upper terrace is there about 170 feet. It now becomes comparatively obscure, while the lower entirely escapes observation. In the next recess, called Komagfiord, the latter forms a green mound or terrace of fertile meadow-ground all the way round at from 57 to 64 feet. The upper line is very faint, and it is difficult to say in what manner it is produced. It was not till after many examinations and sightings of the one side of the valley from the other, that I determined its elevation at 179 feet. M. Bravais, who seems to have been under the same difficulty with it, states its elevation at a few feet less. :

It will have been observed, that the rise of at least the upper terrace continues without any interruption throughout the whole of the twenty-five miles within which it is so distinct. From 85 feet at Hammerfest and Hoiée, it has become 179, or 94 feet higher, at Komagfiord. The lower line, though more obscure, and less liable to exact measurement, also manifestly rises within a more limited space, namely, from about 44 at Molstrand to 64 at Komagfiord.

That the markings were made by the sea is, I presume, admitted on all hands. That the land involved in the case has made two angular movements, first, one subsequent to the time when the higher shelf was formed, and then another subsequent to the time when the lower line was impressed, seems also beyond question. These two positions are laid down by M. Bravais, and I believe they are not to be shaken. There remain, however, some interesting points of inquiry, as whether the movement has been regular, in what direction it has been made, and where was the axis of rest ?

That the movement has been regular does, I think, appear from the measurements now presented ; but this point can only be fully settled in connection with the next question, which regards the direction in which the movement has taken place. It will be observed, that the series of elevations from

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Hammerfest to Beritsmol—that is, in a line south-south-east —is tolerably equable in proportion to the space passed over ; but when we turn off into Varg Sund, in a line south-south-west, the rise is much slower. To give particulars: Between Hammerfest and Beritsmol, a space of 114 geographical miles, the rise is 46 feet; but from Beritsmol to Saraby, 9} miles, it is only 24 feet; while from this to Komagfiord, 9 miles more, it is 25 feet. If, however, we form a line nearly coincident with that of the first line of observation, as in the accompanying map, and, prolonging this into the mainland, raise upon it vertical lines touching the various positions in Varg Sund, we shall find that egual spaces are passed through in this portion of the affected district within equal spaces of the

rise. It therefore appears that the rise is not slower in Varg Sund than in the sound between Qualée and Seiland, but only the terrace is there not so coincident with the line of rise. The rise observably becomes accelerated as we pass on to Komagfiord, because the trend of the coast in that quarter gets more into a conformity with the line of rise. The heights taken on opposite coasts, moreover, as at Molstrand and Quisnaes, near Neeverfiord and at Rabastynaes, at Saraby and Olderfiord, correspond pretty well with this theory of the direction of the movement. In short, if a fair allowance be made for inaccuracy of maps, and the indeterminateness of the base line of the measurement (for a high water mark is in some places difficult to hit), it will appear that there is a remarkable approach to equability of rise throughout the whole of the space between Hammerfest and Komagfiord, the rate being pretty uniformly about 4 feet in a geographical mile.

M. Bravais regarded the possibility of the terraces having either risen at the one end or fallen at the other, so as to produce the slope; but he had not probably observed the two terraces which run along the coast to the southward, with little interruptions, for a space of about 180 miles, observing to all appearance, one uniform relation of heights, at 55 and 143 feet. I consider the two sloping terraces of the northern sounds, as a disturbed portion of the system represented by the two southern terraces. If this be a just view, the dis-

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turbed land has moved on an axis of rest, rising at the one end and falling at the other. It has been a see-saw movement, the centre or point of which must be looked for at the place where the two inclined terraces are at the normal height of the system of which they presumably form a part. Keeping in view the upper one only, this place is in the line "near the point of observation at Neeverfiord (see Map, Plate IV.), for the upper terrace is there 143 feet high, being the elevation of the upper line as measured at Tromsde. From that place, the terrace falls 58 feet to the transverse line at Hoide and Hammerfest. How much farther it may have fallen in that direction, has not been ascertained. From the same central point it rises proportionately in the opposite direction.

Does the rise continue farther to the southward than the line of Komagfiord? I was at first of opinion, that it stopped here, instead of going on, as supposed by M. Bravais, to the embouchures of the Alten and Kaafiord rivers, because I found in Kortsfiord, the next opening to the southward of Komagfiord, what I believed to be the upper line, at nine or ten feet below its Komagfiord level. Hence it appeared to me as if that line had here attained a culmination point, and was beginning to descend towards the south. I have since, however, discovered the remarkable fact, that if the line of movement be prolonged till it comes abreast of the mouth of the

Alten, the perpendicular line then raised upon it will pass through the whole range of terraces between that point and the mouth of the Kaafiord river, which are all of them about 220 feet high in front, but rise inland to an entire height of 239 feet ; and this elevation will be just about what might be expected of the upper line prolonged to that point. (See Plate III., Lower View, representing the alluvial terrace of Quaenvig, a good example of its kind.) The uniformity of the elevation of these terraces over a range of 10 miles is in itself remarkable ; their being traversed by the perpendicular line from the line of movement at the point where we might expect the elevation of the terraces to be attained (see Map, Plate IV.), is very striking. Finally, on considering the somewhat extraordinary character of these alluvial formations, I

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became inclined rather to regard them as belonging to a disturbed than to a steady district. The objection from the terrace at a lower level in Kortsfiord may be allowed to give way, for there are so many anomalous markings in that valley, and in Komagfiord (to be presently adverted to), that a mistake may probably have happened. What adds in some degree to the probability of the Alten terraces being part of the district of disturbance, there are similar sandy formations connected with other rivers at Melsvig and Talvig ; and these, being five or six miles less advanced upon the presumed line of movement, are proportionately lower. If we assume that the district of disturbance extends thus far, the vertical movement connected with that disturbance at Alten must be regarded as equal to the difference between 143 and 239, or 96 feet. Does the movement extend farther southward ? We should have to answer in the negative if M. Bravais is right in saying that the great Alten terrace goes for four or five leagues along the valley without change of height ; but this point may be worthy of future inquiry.

M. Bravais indicated the existence of a faint intermediate line, which he observed both at Hammerfest and Alten, and which he conceived to imply an intermediate movement. But the fact is, there are, at many stations throughout the disturbed district, terraces over and above, though mixed up with, the noted two which are here discussed. At Hammerfest, besides the intermediate line alluded to by M. Bravais, which is formed by a grand terrace of blocks fallen from the schistous mountain behind the town, there is, on a hill-face near by, a series of shingle terraces, scantily covered with vegetation, and precisely resembling shingle beaches of the present day, at 87, 123, and 144 feet. There is also a ring terrace of transported matter, topped with water-laid sand, round the Lake of Hammerfest, at 97 feet above the sea. Here, it will be observed, are traces of the sea at not less than three elevations superior to the higher of the two lines. In Rypfiord and at Indre Sioholmen there are also terraces above the higher line. Such is likewise the case at

Qualsund. In Komagfiord, at the entrance of its little river, there is a series of terraces both below and above the lower

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line, besides a broad flat terrace of soft materials on the hill-face at 161 feet, being 18 below the upper line. In Kortsfiord there are similar objects, particularly the terrace already alluded to at 169 feet, and one connected with a mountain streamlet at 241. The distinctest markings of this kind, however, are seen on the faces of the Alten and Kaafiord formations. At Bossikop, Quaenvig (see Plate III., Lower View), and Kaafiord, there is one of marked importance at between 80 and 90 feet, being probably that which M. Bravais set down as the lower line in that district. It appears as a cincture round the singular sandy promontory of Oskarnaes, at a few feet lower; which is what might be expected, as that is a point some way advanced on the assumed line of dip. There are, besides, however, at Quaenvig and Kaafiord, markings equally or even more decided, at 52, 123, 144, and 167 feet, indicating no fewer than three movements between the dates of the upper and lower lines, and at least one subsequent to that of the lower. To establish connections among these markings, would obviously require no small amount of additional observation.

The general fact may now be considered as tolerably certain, that there is a district in Finmark, of 40 geographical miles in extent, which has sunk 58 feet at one extremity, and risen 96 at the other. Its line of dip and of rise is pretty well ascertained. It is not greatly different from that of the magnetic meridian for the district, which is about 11° west of north. The movement has been surprisingly equable over relative proportions of the space. A shift of the relative level, after the manner of the Alten and Hammerfest terraces, is, however, exceptional, for there is a much larger district to the south, which has evidently been involved in this process of shift at the same time, but where that shift has taken place without being attended with a change of the plane originally observed by the land. In the central and southern districts of Norway, there are other ancient sea-markings, which appear to preserve horizontality, and even awaken the surmise, that they coincide with similar levels in other countries.

There is, however, a large tract in the south and east of

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Scandinavia which is ascertained to be undergoing an elevatory movement, even at the present day. I was able to visit the celebrated stone at Lofsgrund, near Gefle, on the Gulf of Bothnia, which has been marked with the height of the

water at various periods; lastly, by Sir Charles Lyell in 1834. I found his mark 2 feet 7 inches below that of 1731; and the sea, on the day of my visit (2d September), was about 6 inches below Sir Charles's mark, or rather more than 3 feet below that made 118 years before. It occurred to me as unfortunate to have selected for this kind of test a loose block lying near the shore; for we cannot exclude the suspicion, that the ice may carry it a little way up the beach every winter. Nevertheless, as there are other marks presenting similar results, where no such liability to fallacy exists, the probability is, that no movement has actually taken place. Two days afterwards, I visited the mark made by Flumen upon the cliff of Grasée, near Oregrund, in 1820. The sea was so calm as not to wet more than an inch of the cliff above its ordinary level of the day; and the seamen informed me, that the water was ata very fair average forthe season. I found the surface of the water 11 inches below Flumen's mark, which had been made only nine days later in the year. Thus, if the sea at the two periods was in similar circumstances, or at its mean level for the season, there appeared to have been arise of the land in this district to the extent of 11 inches in twenty-eight years.

A Conjecture as to the Forces which produce the Tails of Comets. By WILLIAM JOHN MACQUORN RANKINE, Esq., C.E. Communicated by the Author.

The immense velocity with which the tails of comets, on the approach of those bodies to their perihelia, are projected in a direction opposite to that of the sun, has always been held to indicate that the particles of those nebulous envelopes are acted upon by some powerful force directed from the sun. Various hypotheses have been proposed as to the na-

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ture and origin of this force ; but they are all more or less inconsistent with known facts.

One mode of accounting for the existence of such a force has, so far as I am aware, been hitherto overlooked.

The nebulous substance of a comet appears to consist of matter in the state of smoke or mist: that is to say, of minute solid or liquid visible particles, suspended in invisible vapour. If we suppose that, on the approach of the comet to its perihelion, each of these visible particles is partially volatilized by the sun's heat, it follows that it will emit invisible vapour, chiefly on the side nest the sun, and that, by the reaction of the vapour so emitted, the portion of the particle which remains in the visible state will be propelled away from the sun, with a force depending on the rapidity of the evaporation. This force will be greatest in the superficial portion of the nebulous envelope, the internal parts being more or less protected from 'the sun's rays. The particles thus propelled, after describing an orbit more or less elongated, will return towards the nucleus under the action of gravity.

Such will be the ordinary action of the solar heat, according to the supposition now proposed, as displayed in the usual form and position of the tails of comets; but it may be modified by other forces, such as the action of jets of vapour issuing from the nucleus, so as to give rise to those forked and oblique tails which have occasionally been observed.

I do not propose this conjecture as a theory sufficient to account for all the phenomena of the tails of comets, but merely as a speculation, somewhat less visionary, and more in accordance with the known properties of matter, than those which have hitherto appeared on the same subject.

EDINBURGH, September 1849.

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On Volcanic and Metalliferous Eruptions. By M. ELIE DE BEAUMONT. (With a Table.)

Voleanic eruptions bring to the surface of the globe, on the one hand, rocks in a state of fusion, lavas, and all their accompaniments ; these are volcanic products after the manner of lavas ; and on the other, substances volatilized or carried along in their molecular state, such as steam, gas, salts, &c.; these are volcanic products after the manner of sulphur.

On going backwards in the course of geological periods, we observe that volcanic substances after the manner of lavas become more and more rich in silica ; and that voleanic substances after the manner of sulphur become more and more varied. The latter are the produce of the humid way, in the same manner as the products of thermal springs are those of heat. The greater part of metallic veins appear referable to this.

The following is a brief summary which M. E. de Beaumont gives of his memoir. The numbers refer to those in the Table at the end of the article.

1. Bodies most generally spread over the surface of the globe. These are sixteen in number.* We may add titanium, bromium, iodium, selenium, which are generally diffused in small quantities, which would raise the number of these bodies to twenty; but of these not above twelve are found frequently and in abundance.

2. Fourteen simple bodies, which enter into the composition of various species of Javas produced by existing volcanoes. Although sulphur is found in sulphuric acid, hydrogen in the water of haiiyne, chlore in sodalite, fluor in mica, yet these four bodies occur in lavas only in an exceptional way, and the number ought, therefore, to be reduced to ten.

3. Fifteen simple bodies, which compose the ancient volcanic rocks.

* See Researches on the Theoretic Portion of Geology. By Sir Henry de la Beche.