Discussion.

Sir R. I. Murchison differed from the author on one point only. He regarded the upper member of these saliferous rocks, which is overlain by 1500 feet of Bunter Sandstone, as completely separated from that formation, and as forming the upper part of the Permian group.

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3. *On the* Formation *of* Deltas; *and on the* Evidence *and* Cause *of* great Changes *in the* Sea-Level *during the* Glacial Period. By Alfred Tylor, Esq., F.L.S., F.G.S., &c.

(Abstract.)

The first portion of this paper is devoted to a comparison of the delta-deposits of the Po, Mississippi, and Ganges, by means of the descriptions of the strata obtained from borings in their deltas for water.

The surfaces of these deltas and the alluvial plains above them are compared together with reference to their inclination and height above the sea-level; and it is found that a parabolic curve drawn through the extremities of each river, and through one point in its course, nearly represents its longitudinal section, the greatest deviation being 30 feet in some of the largest deltas.

The delta-deposits are found to be coarser and more sandy near the bottom, indicating that the rivers were more rapid during the earlier portion of their existence.

Messrs. Wheatley and Abbott's descriptions of the delta of the Mississippi are compared with those of earlier writers; and a description is given, from their work, of the late extensions of the delta into the Gulf of Mexico.

The formation of delta-deposits is explained by the hypothesis of a change in the level of the sea, instead of in the level of the land and sea-bottom.

The littoral deposits around Great Britain are investigated by the author, to ascertain if his hypothesis, of a fall in the sea-level of 600 feet during the Glacial Period, is tenable.

Some evidence of the extent of the Glacial Period is given; and the ice-cap hypothesis advocated by Mr. Croll is alluded to as a probable cause of a great reduction in the level of the sea through abstraction of water from the sea, and its deposition at the poles in the form of ice.

The positions of the fossiliferous strata of the Quaternary Period are discussed with relation to Mr. Godwin-Austen's former suggestion of a great river where the German Ocean now is, formed by the junction of the Rhine, Thames, and Humber. The probable age of the Straits of Dover is also alluded to.

Prof. Forbes's examination of the fauna and flora of the British Isles, with a view to the determination of the sources of Alpine plants, induced him to believe that the British plants and animals migrated from Scandinavia, Germany, and France at different periods, some before and some after the Glacial Period; and the

hypothesis of a fall in the sea-level, in the author's opinion, accords better with the facts described than Professor Forbes's supposition of changes in the level of the land and sea-bottom.

If Mr. Tylor's hypothesis is correct, that there has been a fall of the sea-level of 600 feet during the Glacial period, followed by an equivalent rise, we ought to find evidence of dry land, of rivers, or, at least, of littoral conditions on the bottom of the sea within the 100-fathom line of soundings.

We should not expect to find a very continuous and unbroken land-surface preserved, as in the upward movement of the sea much ground would be covered with deposits of clay, and shingle, and sand, and much of the old surface removed by currents and waves.

Sir Henry De la Beche, Professor Edward Forbes, and Mr. Godwin-Austen have investigated the present condition of the sea-bottom round the British Isles; and in their writings are to be found many observations of facts that may be as conveniently explained by the hypothesis of the change in the sea-level as by that of a change in the level of the land and sea-bottom.

Taking the facts as they stand in the writings of these authors, who have all treated the subject most skilfully, the hypothesis of a gradual fall in the sea-level of 600 feet, the author thinks, explains them equally well or better than that of local elevations and then depressions to exactly the same point. The great difficulty in Professor Forbes's argument was to get the Scandinavian flora across the sea. It was necessary to suppose that the space now occupied by the German Ocean was elevated (of which there is no proof), in order to provide dry land for the plants to pass over. The Glacial Mollusca were found by Professor Forbes living in the deeper portions of the German Ocean, which, the author thinks, showed that there could have been no great elevation of the sea-bottom. Whether the sea-level were reduced or the land raised 600 feet, would have the same effect in producing changes of climate and increased excavating-power of rivers; and he thinks that all the phenomena of a great northern river receiving the waters of the Rhine, Thames, Humber, &c. would occur as described by Mr. Godwin-Austen, if the sea-level were depressed 600 feet.

Mr. Gwyn Jeffreys has lately recorded the discovery of specimens of fossil Arctic shells off the Shetland Isles in about 90 fathoms water. The following species were found by him in dredging, and are arranged in the order of their abundance:—

Terebratula Spitzbergensis.	Trochus cinereus.
Rhynchonella psittacea.	Möllería costulata.
Pecten Islandicus.	Trophon clathratus.
Tellina calcarea.	Columbella haliæeti.
Mya truncata, var. Uddevallensis.	Pleurotoma pyramidalis.

All these shells are found fossil in Sweden, and living in the extreme Arctic seas. None of these species are ever found in deep water; so that their presence, scattered over a wide area of sea-bottom, is remarkable, and corresponds with the discovery of shingle and littoral shells in the English Channel at similar depths. The

littoral shells of the English Channel are not Arctic species, as are those in the German Ocean; and this fact is a proof that the former were deposited on the sea-bottom of the English Channel before the junction of the English Channel and German Ocean at the Straits of Dover was effected.

The discovery of these nine species of fossil shells by Mr. Gwyn Jeffreys at a depth of 90 fathoms, off the Shetland Islands, is an important addition to Forbes's and Godwin-Austen's observations. This discovery affords independent and corroborative proof of identical conditions with those observed by these authors in other parts of the sea-bottom; and it establishes the existence of littoral conditions in the Quaternary period near the present 100-fathom line in the North Sea, and is therefore an additional support to the hypothesis we are considering.

A fall in the sea-level of 600 feet would not only produce littoral conditions off Shetland, without any change of level of the sea-bottom, but would tend to lower the temperature of the air very much, and also to increase the rainfall. There are certain conditions under which a rainfall of 300 inches per annum might be produced in our climate; but they would involve the summer heat being 130° Fahrenheit near the locality of a mountain-range of from 1500 to 2000 feet in height. The amount of rainfall depends greatly upon the high temperature of the air at the sea-level (supposing it saturated with moisture) and the low temperature of the air on the mountain-range intercepting the aerial currents.

We might have in our latitude a summer heat of 130° from the general elevation of the heat of the globe, from an increased volume of the Gulf-stream, and from a greater prevalence of the west and south-west winds.

The pluvial period which the author had previously proposed, and which was so much objected to in the discussion of May last, does not require any greater volume of water than has been before suggested by geologists, as heights of 80 feet were estimated for the ordinary difference of winter and summer floods in passages of two different memoirs by Mr. Prestwich, as occurring during what he considers the earlier part of the gravel-period *.

There is, however, in England no appearance of tropical vegetation in the Quaternary deposits, such as we should expect would accompany a temperature of 130°; and we must therefore try some other alternative.

We could not have rivers varying 80 feet in summer and winter without some such rainfall, unless we had pluvial and tidal conditions very different from those now in the Thames and Somme Valleys. What we want is to explain the enormous rise of rivers in a cold climate during the Quaternary period.

In the year 1840 the ice brought down by a January flood, gorged at a point about nine miles from the mouth of the Vistula, cut a

* [See Abstract of a paper, by Mr. Prestwich, on the Loess of the Valleys of the South of England and the Somme, read June 19, 1862, Proceedings of the Royal Society, vol. xii. p. 170.]

channel through the sand-hills to the sea. This is now the mouth of the Vistula, that passing Dantzic having been turned into a canal*.

I do not intend here to discuss the question of subsidences and elevations which have affected the surface of the earth so largely, and have no doubt occurred in some localities during the period under consideration. I would, however, remark that in Wealden, Eocene, or Miocene deltas there is no instance of any large fluviatile deposit having been elevated or depressed *evenly* over a large area; while all over the world a perfectly even movement of subsidence is supposed to have taken place just at the mouths of large rivers in the Quaternary, or most recent, period, in order to account for modern freshwater delta-deposits containing shells living in the adjoining seas being now found hundreds of feet below the sea-level.

It would be the safer plan, in considering the remarkable gravel- and crag-deposits which characterize so distinctly the Quaternary period, to infer the size of rivers, amount of rainfall, and elevation of tides from the deposits themselves. Further acquaintance with meteorological phenomena may find a fitting explanation of the difficulties we meet with in explaining the position of the gravel at such heights above our present streams and freshwater clay, and sands at such depths below the sea-level.

If the hypothesis we have been considering is a true one, that the sea-level fluctuated 600 feet in the Glacial period, falling gradually and then rising again to its former level, we ought to find the best evidence in the Pacific Ocean among the vast littoral accumulations of the coral-zoophytes.

The same theory of gradual subsidence, as was proposed for explaining the delta-deposits, has been applied to explain the formation of the remarkable coral-islands over a tract of ocean 5000 miles long. The sea-bottom by this theory is supposed to subside so regularly and slowly that the coral-zoophytes build up their reefs and coral-banks at an equal rate with the fall of the sea-bottom.

Mr. Croll's hypothesis of an immense mass of ice at the poles sufficient to make the polar diameter equal to the equatorial (Phil. Mag. p. 302) is well known. He has (p. 305) assumed that the quantity of liquid water would be unchanged, as the ice in the southern hemisphere would be transferred to the northern hemisphere.

The author's hypothesis is different.

He thinks the geological evidence of a Glacial period indicates an immense collection of ice at the north pole, accompanied by a low temperature in the tropics, and probably a very low temperature at the same time at the south pole.

This would involve the supposition of a fall in the ocean-level in proportion to the quantity of ice collected at the poles.

It is of course doubtful what quantity of water was abstracted from the ocean in this Glacial period (which Mr. Croll considers

* Pfeiffer, 'On the Vistula,' Dantzic, 1849. The gorging of ice at the mouth of the Thames, Seine, and Somme may have assisted in the production of some of the remarkable gravel-beds in these rivers.

commenced 240,000 years ago, and lasted 160,000 years), and was stored up in the polar regions in excess of the quantity now existing there or what existed previously.

This excess must have been an enormous quantity; and if equal surfaces of the globe were covered with ice and with water, then every foot of the average thickness of ice stored up in the polar regions above the former surface-level would cause an immediate fall of the sea-level also of one foot.

The author's supposition of a fall in the sea-level of 600 feet does not appear to him excessive, if the Glacial period was so important as we have reason to suppose it to have been.

Discussion.

The President called attention to the fact that in the neighbourhood of coral reefs the dead corals extend to such a vast depth that, supposing them all to have been formed near the surface, and that surface only lowered by abstraction of water to the Poles, the accumulation of ice must have been so great as to become incredible.

Sir Charles Lyell had already suggested to Mr. Croll that, assuming the accumulation of ice at the Pole depressing the centre of gravity of the earth, the submergence that would have resulted had the quantity of water in the sea remained the same would, to some extent, be counteracted by the reduction in volume consequent on the formation of the ice. With regard to the delta of the Mississippi, the data on which he argued had considerably altered since first he wrote on the subject, inasmuch as recent calculations had doubled the estimated volume of water flowing into the sea, and thus it was capable of producing the same effect in half the previously calculated time. The progress of the delta at any spot was of necessity variable, as the position of the mouth changed. The American engineers had allowed only 40 feet as the depth of the fluviatile deposits, whereas from boring Sir Charles had concluded it to be at least 500 or 600 feet. There was now reason to suppose that it was much more, possibly as much as 1500 feet. This being the case, notwithstanding the amount of work done by the river being doubled, his calculation as to the time required for the formation of the delta might not after all be so excessive.

Mr. Prestwich suggested that Mr. Croll's theory involved probably a transfer of ice from one Pole to the other, and not only a diminution of volume of the sea. The raised beaches round the coast of Britain varied considerably, and were not on one uniform horizon, as they must have been had they resulted from a lowering of the sea. The elevation of the old sea-beds during the Glacial period could not be accounted for by any supposition of the mere alteration in the volume of the sea.

Mr. Evans pointed out that, the *Cyrena* being a freshwater shell, its position at a certain level was not connected directly with the height of the sea. He doubted the curve of the rivers being in all cases parabolic.

Mr. Mallet had remarked that nearly all river-courses are in longitudinal section hollow curves which do, in their upper reaches at least, appear to present more or less of the character of parabolas. But although the well-known formula which expresses the discharge at each point, and in fact the regimen of the stream, might seem *à priori* to countenance the idea that these curves are parabolic, he is much disposed to think that the form of water-channel does not depend upon any hydrodynamic law, but simply upon the natural contour of the longitudinal sections of the river-courses, which run almost always on the bare rocky skeleton of the earth, and follow the forms, viewed on a broad scale, of all rocky anticlinals, whose slopes are always more or less hollow curves. As regards the long gently sloped lower reaches of all rivers, and more particularly of great rivers, such as those appealed to by the author, Mr. Mallet believed that it would be perfectly impossible to affirm that their longitudinal sections conformed to any particular curve. When plotted, such sections will be found to fit equally well to right lines, or, if curved, to parabolas, ellipses, arcs of circles, or what we please.

Mr. Tylor replied that he had not found definite evidence as to the extension of corals downwards to such a depth as that mentioned by the President. With regard to oscillation, he had merely treated of the southern part of England. The opening of the Straits of Dover would account for the existence of beaches above the present level, as the tides would have previously risen higher. The parabolic curve was that which, by actual comparison, coincided most closely with the longitudinal section of the banks of the rivers Po, Mississippi, and Ganges.

November 25th, 1868.

The following communications were read:—

1. *On* Floods *in the* Island *of* Bequia. By G. M. Browne, Esq.

(Communicated by the Secretary of State for Foreign Affairs.)

[Abstract.]

On the 17th of March, at 8 o'clock P.M., a steady strong wave was seen bearing down upon Admiralty Bay; it had no perceptible crest, and was 3 feet in height; it encroached upon the land to distances varying from 70 to 350 feet. A second, smaller wave followed. No shock of an earthquake was felt.

Discussion.

Dr. Duncan wished for some explanation of these earthquake-waves, more especially with regard to the effects of supposed cataclysmic waves. He considered that they arose from sudden changes in the level of shoals or littoral tracts, and not from deep-sea disturbances.