LIVERPOOL GEOLOGICAL ASSOCIATION,

6th February, 1882.

At the Ordinary Meeting, held this date, at the Free Library, Mr. Henry Bramall, M. Inst., C.E., President, in the Chair, the following gentlemen, proposed on 9th January, were elected as Members:—

Messrs. Hopkin Thomas, T. H. Williams, John A. Tate, W. Houlding, C. H. Morgan, William Hills, W. R. Roughsedge, Bruce M. Broadfoot, and Frederick Marrow.

Proposed as Members:—

Messrs. James Plastow, 169, Great Homer Street; Samuel Duff, 55, St. Martin's Cottages, Ashfield Street; Arthur J. Dunsford, Wynch House, Seacombe; P. B. Deuchar, 17, Kingsley Road, Liverpool.

DONATIONS.

Index to first 25 vols. of "Transactions," from the North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne. Reports Nos. 9 and 10, (1879-80; 1880-81.) and "Proceedings," Nos. 1 and 2, (1874; 1878.) from the Chester Society of Natural Science. "Rules, &c.," of the Liverpool Science Students Association, from the Association. "On the varieties of the Shells belonging to the genus *Nassa*," and other papers, by Frederick P. Marrat, presented by the Author.

The following Paper was read:—

"RIVERS."

By T. Mellard Reade, C.E., F.G.S. F.R.I.B.A

The selection of the subject of the paper I have been asked to give to you to-night, with a geological audience such as I am addressing, demands little or no explanation. To those who have paid much attention to physical geology, the profound significance of the silent action of the RIVER, not alone in modifying the surface features of the land, but in the actual construction of the crust of the earth, scarcely needs emphasising. Yet I venture to think that the surface action, which is visible to us, has been dwelt upon rather to the exclusion of the re-constructive action of the RIVER, and this latter's relation to the sphere we live on, I hope partially, if inadequately to develop.

To begin at the beginning, we may ask ourselves, what is a RIVER? An application to our good friend the dictionary will tell us that the word is directly derived from the French *riviere*, a river, or in old French, a bank, shore, or country on the banks of a river. Its real origin no doubt being the Latin word *ripa* a bank or shore. We thus see even in the early stages of civilization the relations of the water of the river to the valley in which it runs was recognized, though it has been left to us moderns to incontestably prove that the valley itself is the work of the running water.

The absolute necessity of the river to mankind and to the supply of their wants, as well as the instinctive recognition of it as a grand natural feature, has, from the earliest ages, invested it with the deepest poetical sentiments and associations and even often with a sacred character; as was the Nile, the Jordan, the Tiber, and as is still the Ganges.

Our poets are full of allusions to rivers. Goldsmith speaks of the "murmuring Loire," Tennyson, of the "brimming river," and Thomas Aird in a beautiful little poem, thus apostrophises the river :—

> "Infant of the weeping hills,
> Nursling of the springs and rills."

Beattie in his "Minstrel," gives this fine picture of river-action—

> "And hark! the river, bursting every mound,
> Down the vale thunders, and with wasteful sway,
> Uproots the grove, and rolls the shattered rocks away."

Thomson's Seasons are full of beautiful descriptions of river scenery, and rivers in their varying moods. Speaking of the Nile, he says in "Summer,"

> "Rich king of floods! o'erflows the swelling Nile."

And after tracing his origin

> "From his two springs in Gojam's sunny realm,"

continues

"He sports away
His playful youth, amid the fragrant isles
That with unfading verdure smile around.
Ambitious, thence the manly river breaks;
And gathering many a flood, and copious fed
With all the mellowed treasures of the sky,
Winds in progressive majesty along;
Through splendid kingdoms now devolves his maze;
Now wanders wild o'er solitary tracts
Of life-deserted sand; till, glad to quit
The joyless desert, down the Nubian rocks
From thundering steep to steep, he pours his urn
And Egypt joys beneath the spreading wave."

And in "Winter" is a description of a river, remarkable as containing what is now a recognized geological truth, or feature peculiar to river valleys, the final gorge through which most rivers cut their way to the sea.

"Wide o'er the brim, with many a torrent swelled,
And the mixed ruin of it's banks o'erspread,
At last the roused-up river pours along;
Resistless, roaring, dreadful, down it comes,
From the rude mountain, and the mossy wild,
Tumbling through rocks abrupt, and sounding far;
Then o'er the sanded valley floating spreads,
Calm, sluggish, silent*; till again, constrained
Between two meeting hills*, it bursts away,
Where rocks and woods o'erhang the turbid stream;
There, gathering triple force, rapid and deep,
It boils, and wheels, and foams, and thunders through."

A more exact description of a river it would be difficult to find, even in a geological work; such is the prophetic insight of the poet, when seizing the salient features of nature.

But however refreshing to a scientific mind to take a dip into the poets, or, to make a joke, their rivers, we must come at last to the more literal, leaving the impressional behind.

Looked at purely from a physical point of view, a RIVER is a main drain for part of an island, or a continent. A channel that has been made by the ceaseless rushing of water for untold ages, a silent highway by which water taken up by evaporation in the atmosphere from the great oceans, condensed in the form of rain, returns again to the sea in a collected form, along a line of least resistance. To those who are not familiar with the science of hydrography it is difficult to realize the mighty effect of the fall of a small quantity of rain, if spread over a large area. Engineers have a ready way of calculating it, for one inch of rain spread evenly over an acre weighs as nearly as possible one hundred tons. This fact of itself is sufficient to show what mighty mechanical work a river can do. A fall of one inch of rain a day is not an unfrequent occurrence, even in this neighbourhood. There were in 1880 *six* such falls, and on one occasion in July, 1877 I registered 2¼ inches in twenty-four hours. In thunderstorms an inch may fall in an hour, but these falls are mostly local, and restricted. It is on the occasions of heavy continuous falls that havoc is done, such as Thomson has so well described. If the rainfall were spread evenly over the whole of the year, the rivers would easily and silently carry off all the water that falls upon the land, but their valleys would shew characteristics they do not generally possess.

But a consideration of the enormous quantity of water which collects in a large river from its basin will aid us in understanding the extraordinary effects of what is called subaërial denudation—a subject that requires an education to appreciate.

We who live by the sea are familiar enough with the mighty action of the wind wave, because its force is concentrated and its action can be seen and measured, but the silent work of rain requires *reason* and *investigation* before it is appreciated. The effects of the river in flood are more nearly related to those of the sea in a storm. They both act principally mechanically, and both tear up deposits they have laid down in their quieter moods, as well as grind down hardened rocks deposited under different conditions ages ago.

But as the ocean is the feeder of the river with water through evaporation and condensation the river repays the debt by bringing within the ocean's mighty arms the wrecks of the land; returns to him the materials of the rocks, which for a time the elevatory forces of heat within the earth have robbed from his realm Thus is the constant circulation kept up, the life, the death, and the renewal which has been uninterruptedly going on from the earliest dawn of geologic time, and which is still, so far as we can measure and infer, as active as ever.

Those who have not considered the subject, and even some geologists still have a difficulty in understanding how the present rivers could have cut out the valleys in which they run. Hence the invention of such things as Mr. Tylor's "Pluvial" period during which time he credits the rivers with a supply of water nine times and a power of denudation 729 times as great as that of the present*. There is no doubt that every river basin must have had its fluctuations of rainfall within certain limits; but there is no reason to suppose that on the whole there was more or less rain in previous periods than now; at all events the onus of proof lies on those who assert that there was. But such is the constitution of the human mind that it often fails to recognise the tremendous effects of small recurrent causes.

I will try to explain in as simple language as I can command the mode in which the great majority of geologists recognise that the rain and rivers have worn away the land.

That the question may be considered in its simplest form I will select as an example a country where the rocks that have been eroded have preserved a tolerably horizontal arrangement, and we could hardly have a better one than the Peninsula of India. In the manual of the Geology of India by Medlicot and Blanford, they say, "The peculiarity of all the main dividing ranges of India is, that they are merely plateaus, or portions of plateaus that have escaped denudation. There is not throughout the length and breadth of the Peninsula, with the possible exception of the Arvali, a single great range of mountains that coincides with a definite axis of

* Geological Magazine, November, 1881, page 525.

elevation, not one, with the exception quoted, is along an anticlinal or synclinal ridge. Peninsula India is in fact a table-land worn away by subaërial denudation, and perhaps to a minor extent on its margin by the sea, and the mountain chains are merely the dividing lines left undenuded between different drainage areas. The Sahyádri range, the most important of all, consists to the northward of *horizontal, or nearly horizontal* strata of basalt, and similar rocks, cut into a steep scarp on the western side by denudation, and similarly eroded, though less abruptly to the eastward. The highest summits, such as Mahábleshwar, (4,540 feet), are perfectly flat-topped, and are clearly undenuded remnants of a great elevated plain. South of about 16° north latitude, the horizontal igneous rocks disappear, and the range is composed of ancient metamorphic strata; and here there is in some places a distinct connection between the strike of the foliation and the direction of the hills; but still the connection is only local; and the dividing range consists either of the western scarp of the Mysore plateau, or of isolated hill groups, owing their form apparently to denudation. Where the rocks are so ancient, as those are that form all the southern portion of the Sahyádri, it is almost impossible to say how far the original direction of the range is due to axes of disturbance, but the fact that all the principal elevations, such as the Nilgiris, Palnés, &c., some peaks on which rise to over 8000 feet, are plateaus and not ridges, tends to show that denudation has played the principal share in determining their contours."* From this description we would infer that these plateau rocks, consisting of three great groups, viz. the Vindhyans, Gondwánas and the Deccan traps, the latter supposed to be of cretaceous age, must have been exposed to the wearing action of atmospheric causes for untold ages; and in fact we are informed by the same high authority "there is evidence of a singular permanency of conditions, and freedom from severe disturbance at all periods after early palœozoic times." It is thus seen that we here are not troubled with the peculiar complications in

* **Manual of the Geology of India, introduction, page v.**

the history of the river systems, which Ramsay has done so much to unravel in this country and Europe.

As the Peninsula of India gradually rose out of the Palæozoic Sea the rainfall would establish for itself certain lines of drainage. There is every evidence to prove that the upheaval of a continent is an extremely slow process and if this be so, the initiatory stages of the river system would begin on islands. The tilt of the strata however small would suffice to determine the direction of the flow, the atmosphere would find out the softest rocks, and as disintegration took place through chemical action the mechanical action of rain-wash would clear away the smaller particles. Two great causes would therefore operate; the slopes or gradients, and the nature or texture of the rocks. As the land rose out of the sea these lines would be, so long as it was free from great disturbances or lava flows, unalterably determined. Once the drainage lines have become traced on the continent the rest will follow with certainty, the rivers will deepen their beds, the atmosphere and rainwash will widen the valleys, the same will follow with the branches, and these eventually widening and coalescing, the river basin will be formed. The deepening will go on until the grade to the sea is lowered to the non-erosion point, when changed conditions may make portions of the river valleys areas of alluvial deposit That this has taken place over and over again in every part of the globe is incontestably proved, but it is only seen by the *eye of reflection;* the process is so slow. The mode in which the excavation takes place will vary according to the character of the country and the slope. Near the mountains where deep and steep gorges are cut, the sides of the streams are undermined and boulders formed and hurried along. These may be ground to powder by mechanical attrition before they reach the sea, or they may be laid down as riverine conglomerates, such as the Sivalik conglomerates* in the extra Peninsular area of India, or in the old river-beds of California, afterwards capped by

* Manual of the Geology of India, vol ii. p. 525.

lava flows, as described by Mr. Joseph Le Conte*. But it is not in this way that the largest amount of denudation takes place, that is silent, unseen, due to the disintegration of the rock by chemical causes, which eventually produces particles fine enough to be carried away mechanically by rainwash. If we could only notice it we should find every particle of superficial earth or soil on the travel. The process is slow, but if it were not slow no soil would be left for vegetation to luxuriate in. It by no means follows that the rate of disintegration of rocks is directly proportional to the rainfall; slow percolation moisture, alternate wet and dry conditions, alternations of heat and cold, will be more efficacious than deluges of rain, though the nature of the conditions for most rapid disintegration differs with the nature of the rock itself. The mechanical effects of floods seems to be that of the removal at intervals of the accumulated effects of atmospheric corrosion. If I may be allowed the simile, the disintegrating chemical action of the atmosphere is the navvy's pick that loosens the material, the rainwash is the shovel by which it is thrown into the cart, wagon, or barge, represented by the river, the valley is the highway by which it travels to the sea, to be finally tipped on the tipping bank, the delta, or washed by currents far out into the open ocean. But lately Mr. Darwin has shewn in his work on "Mould and Earthworms" that there is another excavator at work almost equally ubiquitous, that on every acre of ground, when the conditions are favourable, throws up ten tons of earth per annum. Digging deep down into the superficial soil this busy little animal throws up on the surface in agglutinated wormcasts all the particles small enough to pass through its body. Thus is not only introduced a soil-sifter but Mr. Darwin points out that by repeated passages through the body of the animal the material must be ground together as in a little mill. It is evident that if the estimate of ten tons to the acre be a true one, the superficial soil must again and again pass through the bodies of worms, for it is equal to 6400 tons per square mile per annum, or over ten times the

* American Journal of Science, 1880. p. 176, vol xix.

most liberal estimate of the mean denudation of the land.* To Mr. Darwin is due the discovery of this new geological agent. Although man has had worm casts before his eyes from the beginning he never realized that it meant anything important, but genius and calculation show that it does.

We may say of the earthworm

No human being is so fine,
Or skilful at the sap and mine,
The little creature makes no bones,
To dig and drop the greatest stones,
Without the aid of "Jack" or pushing,
Or fear of a dreadful crushing.—
No greater digger was since Adam,
He digs and burrows through Macadam,
And even heaps his little pile
Upon the Roman pavement tile,
And in old buildings maketh merry,
Or even ruined cities bury,
Preserving them for Antiquary,
From this 'tis true the earth is blessed in
Passing through the worm's intestine,
And fields and flowers shew the plan
The worm is nature's husbandman.

But the river does not only carry "dirt" it sweeps away an enormous amount of matter in solution, principally in the form of carbonates and sulphates of lime, a quantity I have estimated for England and Wales, at a mean of 143½ tons per square mile annually.† This matter is swept out to sea, diffused through the great oceans and there appropriated by foraminifera, corals, pelagic molluscs calcareous sponges &c., for the formation of their tests, or skeletons as the case may be.—The matter in suspension on the other hand is principally deposited nearer home, partly on the river-flats in the form of alluvium to be again dug into and swept away, when the river in flood changes its meandering course, cuts

* See "Chemical denudation in relation to Geological Time," Mellard Reade—page 29, where it is estimated at 600 tons per square mile annually.

† "Chemical denudation in relation to Geological Time," page 20.

straight across a loop and hurries everything pell mell before it. To take an illustration from near home, the contractor for the laying of the sewerage pipes from Wigan to the farm below Newborough informed me that he cut through some of the old beds of the river Douglas no less than a dozen times, in a space of 14 miles. But by far the larger part of the "dirt" is carried forward to the point where the river debouches into the sea, or it may be a lake, and is there deposited. These deltas, as they are called, may be well seen in some of the Swiss lakes, or to come nearer home, in our own lake district, but the most remarkable examples are those mentioned in the first report of the newly organised American Geological Survey, as occurring in the now dried up basin of Lake Bonneville, at various levels, making striking features in the topography of the district. This ancient lake of which the Great Salt Lake is but a sorry and alkaline remnant, was as large as lake Huron, but its peculiarity is that the drying up has been so geologically recent, that the deltas of the rivers entering it have been left at various levels around its margin. They might not inaptly be described as "terraced deltas," Mr. Gilbert says.* The Great Salt Lake Desert and congeries of valleys connected with it, were filled with water at a period so recent that the vestiges of the flood are little impaired at the present time. The sea cliffs that were carved by the dash of the ancient waves are sea cliffs still, though they stand a thousand feet above the present level of the Great Salt Lake."

Let us now direct our attention to several continental rivers. The Danube and the Rhine in Europe; the Nile and the Congo in Africa, the Ganges and the Yang-tse Kiang in Asia, the Mississippi and Colorado in North America, and the Amazons and La Plata in South America, may be cited as typical examples. Of these the fullest and most accurate records relate to the Nile, the Danube and the Mississippi. The Nile, which from the earliest ages of Egypt had been an object of solicitude to the multitudes living on its banks, has

* First report of U.S. Geological Survey—page 24.

lately from the scientific investigations of Mr. Fowler, the engineer to the Khidive, yielded us some very accurate knowledge. He finds that in 1873 the minimum measured flow was 355 cubic metres per second, Linant Bey states that the volume of water passing down the river at Cairo from measurements during three "high Niles" was 8166, 9460, and 9740 cubic metres per second,* thus it is seen that the flow of the high Nile is some 26 times that of the low Nile. The suspended matters in Nile water according to the late Dr. Letheby† varied from 4.772 parts per 100,000, in May 1875, to 149.157 in August 1874. A consideration of these simple facts gives us an accurate insight into the denuding and transporting power of a river, showing that it varies most enormously, delivering in the particular case of the Nile 850 times as much matter in suspension during flood, as during extreme dry weather flow. Neither the amount nor the proportion of solid matter dissolved in the water is, as I have often pointed out before, subject to such great fluctuations.‡ In the case of the Nile it ranged from 13.614 to 20.471 per 100,000 parts in 1874, or in other words the Nile in flood brings down 41 times more matter in solution than it does during low Nile. This is a very important fact having a considerable bearing upon questions of physical geology, and has not hitherto been properly considered, but I hope in the end by continued iteration, and presenting the fact in various forms, to insense Geologists into its importance at last!

It will take too much time and become wearisome to develop this part of the subject to any great extent, but it will be instructive to compare these figures with those of the Danube. The extreme low water flow of this river is given by Sir C. A. Hartley at 70,000 cubic feet per second, or 1,982 cubic metres, and an extraordinary flood 1,000,000 cubic feet per second, or 28,316 cubic metres, the flood being thus over 14 times the dry-weather flow. The smallest delivery of suspended matter per day of 24 hours is stated at 11,000

* "The Barrage of the Nile."—Engineering, March 17, 1876.
† "Egyptian Irrigation second Report," page 28—J. Fowler.
‡ Chemical Denudation in relation to Geological Time"

tons, the greatest, 2,500,000 tons; or a variation of 227 times. Great as this variation is, it is seen that the river in this respect does not reach the extremes of the Nile.

The next thing I must touch upon is the *age* of rivers. If the principles I have feebly attempted to lay down are correct it follows as a consequence that most continental rivers of any pretensions are of great antiquity; ancient they are, even as measured by geological time. Professor Ramsay,* who of all geologists has paid most attention to this subject, considers that the valley of the Severn is of immediate post-Miocene date and is one of the oldest in the lowlands of England; he is also of opinion that the Rhine, as it now exists is post-Miocene. In a paper on the Physical History of the valley of the Rhine,† he says; "but this seems certain that, after the post-Miocene upheaval of the Alps, the present main drainage of the area began before the glacial episode and was in many important respects only established by the influence of glaciers." To quote a still more recent writer, Captain Dutton in his admirable report on the Geology of the high plateaus of Utah, which may be termed a monumental monograph on erosion; speaking of the River Colorado he says impressively: "now the grand truth which meets us everywhere in the plateau country, which stands out conspicuous and self evident, which is so utterly unmistakable, even by the merest tyro in geology, is this: *the river is older than the structural features of the country.* Since it began to run, mountains and plateaus have risen across its track and those of its tributaries; and the present summits mark less than half the total uplifts. The streams have cleft them to their foundations. Nothing can be clearer than the fact that the structural deformations unless older than Tertiary time, never determined the present courses of the drainage. The rivers are where they are, in spite of faults, flexures and swells, in spite of mountains and plateaus."‡

* Physical Geography of Great Britain, fifth edition.—page 510.

† Quarterly Journal of Geological Society, 1874, page 85.

‡ Geology of the High Plateaus of Utah.—page 16, 17.

If these are correct inferences, certain consequences follow which seem to have been strangely lost sight of by geologists. Great efforts have been made to estimate the age of deltas. Lyell was the first to attempt it, and all honour to him for his intrepidity. The delta of the Mississippi, Lyell calculated, must have taken 67,000 years to accumulate, but the more accurate survey of the river, by Messrs Humphreys and Abbot, reduced the estimate to 33,500 years, but in the tenth addition of his "Principles" (1867), Lyell very fairly observes—"On the whole I am not disposed to regard the estimate which I made in 1846 of the time required for the accumulation of the delta, as extravagant. The rate at which the river accomplishes a given amount of work is no doubt nearly double what I supposed, as shown by Messrs. Humphreys and Abbot; but on the other hand the quantity of work done, or of mud and sand which has been carried down into the gulf, is far greater than that which I assumed as the basis of my calculation."* Of the justice of these remarks, I have not the slightest doubt. I think that further enquiry would tend to increase the estimate, for no one can say that the crust of the earth is mainly composed of deltaic deposits, so that if the larger part of the denudation of the land going to make up future rocks is subaërial and therefore must have travelled to the sea by rivers, it follows as a consequence that the larger part is by some means or other distributed by the sea, as marine deposit, and therefore this marine portion must be abstracted from the deltaic accumulation, if our estimate is to be correct. Saving the question of the variation of rainfall, in the river-basin this mode of calculation will only give us the absolute minimum age. I am of opinion, also, notwithstanding the "Challenger" experiences, for in her cruise she avoided seas opposite the mouths of great rivers, that mechanical deposits are more widely spread than is generally thought. Some rivers such as the Parana in South America bring down matter so finely divided, that months of repose will

* Principles of Geology, Tenth Edition, volume 1, page 462.

not render the water clear.* Is it to be supposed that such water getting into ocean currents will not be distributed far and wide?

One of the peculiarities of the great continental rivers, which I have never seen satisfactorily accounted for, is that the beds are usually far below the present surfaces of the deltas. I could not say it is never otherwise, but in all cases that I know of, where borings have been made, many hundred feet of deltaic deposits have been pierced before the bed-rock was reached. That is a geological nut to crack. But this is not the time or place to crack it. Oscillations of level have taken place, no doubt evidences of them are to be found everywhere, but why should the Ganges and the Mississippi apparently be both at the lowest swing of the pendulum?

My sketch of rivers and river action is but an imperfect one. The examples I have given have been chosen from those most accurately ascertained, but they are small ones. The River Plate according to observations of Mr. Bateman. the the eminent hydraulic engineer, delivers in dry weather 670,000 cubic feet per second, "a quantity equal to the mean volume of 33 years passing down the Mississippi." Dr. Behm estimated the mean delivery of the Congo at 1,800,000 cubic feet per second, Burton at 2,500,000 cubic feet, but these estimates are mere rough approximations. The Yang-tse at Hankow is estimated at 650,000 cubic feet per second,† while the mighty Amazons rolls to the Atlantic a mean flood of from 2,700,000 to 3,510,000 cubic feet per second. Thus that "father of waters," the Nile, sacred from its historical and scriptural associations, is now, whatever it may have been in earlier geologic time, but a pigmy as compared to a giant, when we think of the Colossus of the American continent, the relations of the flow being, assuming the determinations to be correct, as 1 to 33, that is, the Amazons has 33 times the volume of the Nile.

* George Higgin, Proceedings of Institution of Cival Engineers, vol. 57. page 272—293.

† Nature, September 23rd, 1880, pages 486-7.

I have not exhausted my subject, but I may have trespassed on your patience, though I trust I have made plain some of the functions of rivers in the geological economy of nature. It is wonderful to reflect that these enormous water powers which modern enterprise with scientific audacity proposes to utilize as motors, hundreds of miles from their source by means of the ubiquitous electric circuit are all due to the condensation of invisible vapour drawn up by that father of life, our sun. In the words of Thomson, I may fitly conclude :—

"Those rolling mists, that constant now begin
To smoke along the hilly country, these,
With weighty rains and melted Alpine snows
The mountain cisterns fill,—those ample stores,
Of water, scooped among the hollow rocks,
Whence gush the streams, the ceaseless fountains play,
And their unfailing wealth the rivers draw."