SOLAR HEAT.

The Retardation of the Earth's Motion on Its Axis by Solar Influence—An Important Paper by Captain John Ericsson.

At the meeting of the National Academy of Sciences held at Northampton, Massachusetts, last week, an important paper by Captain John Ericsson, the celebrated inventor, was read, the subject being "Constancy of Rotation of the Earth Incompatible with Solar Influence." The paper was accompanied by the following letter from the author:

NEW YORK, May 27, 1869.—Dear Sir:—I have the honor to present to you, for the National Academy of Science, an extract from an "Essay on Solar Heat," upon which I am now engaged. Also, two partially finished plates necessary to elucidate the subject. It is proper to observe that I have made numerous experiments to ascertain practically if solar heat can be rendered available as a motive power, and that I have constructed several solar engines, some of which have attained a very high rate of speed, fully establishing the practicability of the scheme. These experiments have led to a careful consideration of the dynamic energy of the sun's radiant heat, together with investigations relating to some important practical results of solar heat.

I may mention, also, that in order to facilitate the investigation I have constructed a solar calorimeter and a solar thermometer, by means of which it has been possible to determine with absolute precision what Sir John Herschel and M. Pouillet ascertained approximately some thirty years ago. Indeed, such a degree of precision has been attained that the temperature and dynamic energy established by my instruments indicate with considerable accuracy the eccentricity of the earth's orbit. Thus during the present warm weather the real temperature produced by exposure to the sun's rays at a given zenith distance, as well as the dynamic energy developed, in units of heat, is far less than during the last winter solstice, when the temperature was scarcely 15 deg. above Fahrenheit's zero.

The intended essay, which I expect will be published in about three years, will contain detailed engravings of the several instruments employed in the investigation, together with copious tables relating to the observations made. The most important fact intended to be established will be the dynamic energy of the sun's radiant heat before it enters our atmosphere, as well as the actual temperature of the sun's rays before influenced by the atmosphere and its vapor, or by terrestrial objects. I need hardly observe that *reliable* tables of the dynamic energies and temperature of the sun's rays, for each degree of zenith distance from 6 o'clock in the morning to 6 o'clock in the evening, will furnish precise data for determining the diminution of energy and temperature during the passage of the rays through the atmosphere, irrespective of the nature of the cause of that diminution.

Already the investigations have advanced far enough to justify the assertion that the temperature of the moon under the full effect of the sun's vertical rays will be determined with positive accuracy. It will also be satisfactorily shown that the inferior planets are not subjected to such a destructive heat as supposed, and that the temperature of the sun and the amount of heat constantly parted with have been greatly overstated.

In a future communication I will present particulars which cannot fail to interest you. I cannot, however, omit to state before concluding, that the observations made last winter positively disprove the accuracy of Sir John Herschel's estimate that, owing to the eccentricity of the earth's orbit, the temperature in the Southern hemisphere during our winter solstice is 23 degrees higher than during our summer, on the assumption that the absolute zero is 239 degrees below Fahrenzeit's zero. * * *

I am, dear sir, yours truly,
(Signed) J. ERICSSON.

Professor John Henry, President of the National Academy of Science, Washington.

P. S.—It will afford me much pleasure to forward to you shortly a copy of the annual records of the University of Lund, in Sweden, for the present year, containing some of my speculations with reference to the physical constitution of the moon's surface. My investigations by means of the solar calorimeter and solar thermometer, prove conclusively that the temperature of the moon's surface under the full effect of a vertical sun, owing to the absence of an atmosphere, is not sufficient to render mercury fluid—much less will snow melt under such a low temperature. The irresistible inference I draw from this fact is that our satellite, in place of being a "dried-up, sun-scorched body," is covered with ice and snow, the peculiar reflection observed resulting from enormous masses of ice upheaved and broken, during the cooling and consequent contraction of the body, while the peculiar formation of the general surface, the innumerable circular cavities so unlike anything which the internal heat of the earth has produced, is the result of hot water forced out by contraction, scooping out the ice, and forming those vast surrounding banks of snow and congealed water which excite our wonder; ultimately, during the last effort of internal heat, raising those conical projections of ice which, in so many cases, stand isolated in the middle of the flat bottoms, the frozen oceans and lakes.
J. E.

Captain Ericsson's paper reads as follows:—

CONSTANCY OF ROTATION OF THE EARTH INCOMPATIBLE WITH SOLAR INFLUENCE.

Investigations relating to solar heat, undertaken chiefly with a view of ascertaining accurately how far the dynamic energy of the radiant heat of the sun can be made subservient in producing motive power for the various uses of civilized life, have led me to consider, among other important practical manifestations of solar energy the abrasion of the earth's surface, caused by the flow of rain water in its course to the sea.

The expenditure of force during the transit of the abraded matter from the land to the sea called for on account of friction and other resistance not having a direct bearing on the question intended to be discussed, I will at once enter upon the main subject, the consideration of the effect produced on the rotation of the earth by the *change of position* of the enormous masses of matter detached by the flow of rain water. It is evident that the effects resulting from the change of position of the matter abraded are twofold as regards the earth's axial rotation. In the first place, this matter is brought nearer to the earth's *centre*, excepting in a few instances owing to the elliptical form; but generally the altered position involves an approach to the earth's centre. It needs no demonstration to show that such approach tends to increase the rotary velocity of the earth, since the weight transferred moves in a less circle at the base than at the top of the height from which it descends, consequently calling for the extinction of a certain amount of its *vis viva*. The increase of rotary velocity imparted to the earth from this cause is, however, almost inappreciable. Secondly, the abraded matter, besides its change of position relative to the earth's *centre*, will, in its course toward the sea, either approach the equator or recede from it. In the former case the change will cause a retardation, while in the latter it will augment the earth's rotary motion round the axis. The vastness of the amount of force thus continually operating, the first-mentioned tending to abstract and the last-mentioned to impart *vis viva*, will be readily conceived, on reflection that there are only four important continents, two in each hemisphere, and that consequently the distance from the centre of the principal river basins to the sea is so great that the matter detached from the land by the flow of rain water is carried over 20 degrees of latitude, in some instances. Hence it is removed from or brought nearer to the axis of the globe many millions of feet. An augmentation or a diminution of circumferential velocity, amounting in some cases to 200 feet per second, consequently takes place during the transfer of the abraded matter from the river basins. Bearing in mind that a speed of 200 feet per second corresponds with a fall through a space of 625 feet, we can form an idea of the enormous force of which the earth has been deprived during the formation of deltas produced by rivers flowing towards the equator.

The matter composing the immense deltas of the Ganges and the Mississippi, in order to acquire an augmentation of circumferential velocity corresponding with that of the outlets of those rivers, has demanded an expenditure of force so vast—a force which the earth has supplied—that astronomers might look in that direction for an explanation of some of the retardation which the lunar tables reveal. Unquestionably the Mississippi, Ganges, and Indus alone transfer a sufficient quantity of matter in the direction of the equator, and thereby continually extinguish so great an amount of the earth's *vis viva* that, unless it can be proved that the loss thus sustained is counterbalanced by the operation of the general river system of the globe, a retarding force must be admitted to exist sufficient to diminish sensibly the rotary velocity of our planet in the course of ages.

THE MISSISSIPPI BASIN.

The question whether such a proof can be furnished, or the fact established that retardation actually takes place, is not by any means so absurd as might at first appear. It is true, we do not know what quantity of water or sediment is carried to the ocean by the several rivers; but we can compute with sufficient precision the extent of the river basins. Accordingly, if we could establish a mean of discharge of some very extensive basin, comprising all the variates of climate and soil, the question could be satisfactorily answered. Fortunately there is one river, and that the longest on the globe, draining the greatest extent of surface, with but one important exception, which has been accurately, thoroughly examined, viz., the Mississippi. Not only has this great river been thus examined, but it comprises every variety of soil and climate, its source being among snows and lakes frozen during a great portion of the year, while its outlet is near the tropics. How completely the Mississippi basin represents the average of the river systems of both hemispheres will be understood from this fact, that although the rain gauges at its northern extremity show only thirteen inches for twelve months, those of the southern extremity reach sixty-six inches, with every possible gradation of rain-fall in the intermediate space. In addition to this important circumstance, the basin covers 21 deg. of latitude and 35 deg. of longitude, or 1460 miles by 1730 miles; hence comprising an area greater than the entire European continent west of the rivers Vistula and Pruth. It may be confidently assumed, therefore, that the Mississippi basin represents the average discharge of water and sediment so nearly that calculations based thereon, applied to the river systems of both hemispheres, excepting some of the Northern Asiatic and American rivers, will exhibit a general result differing but slightly from what would be established if all the rivers had been examined.

I propose to present, in another place, a synopsis of some points which bear directly on the subject under consideration, contained in the elaborate official reports on the Mississippi river made by Humphreys and Abbott, 1861, which report reflects so much credit on those officers and the corps of topographical engineers of the United States. Some calculations will, however, be submitted, in this place, based on certain facts established by the reports alluded to, in order to give in advance a distinct notion of the amount of disturbing force which attends the abrasion caused by the action of rain water in its course to the ocean, over the Mississippi basin.

It may be summarily stated that the calculations presented in the reports of General Humphreys and his able coadjutor, founded on observations continued during a series of years, show that the average quantity of earthy matter carried into the Gulf of Mexico, partly suspended in the water and partly pushed along the bottom of the river by the current, amounts for each twelve months to 903,100,000,000 of pounds. This enormous weight of matter is contributed by numerous large branches and upwards of one thousand small tributaries. The mean distance along the streams in which the sediment is carried in its course towards the sea exceeds 1500 miles; but the true mean which determines the amount of force acting to check the earth's rotation is far less.

The annexed maps of the Mississippi river basin have enabled the writer to determine that its centre is situated 70 deg. 10 min. west of the mouth of the main river, and 10 deg. 15 min. north of the same, in latitude 40 deg. 15 min. The reader will find, on inspecting the section of the earth represented on plate 16, that agreeable to the above determination the centre of the Mississippi basin rotates in a circle of 15,784,782 feet radius, and that its velocity round the axis of the globe is 1147·90 feet per second. The mouth of the river, on the other hand, rotates in a circle of 18,246,102 feet radius, with a circumferential velocity of 1326·89 feet per second. It will be seen, on comparing these velocities, that an increased circumferential velocity of nearly 179 feet per second must be imparted to the sedimentary matter during its course from the centre of the basin to the mouth of the river

THE DRAG ON THE EARTH'S ROTATION.

The question here presents itself, where is the motive energy to come from to impart the increased velocity acquired during the transit? We are compelled to answer by an admission that the earth must supply the needed force. In other words, an amount of the earth's *vis viva* corresponding with the force required to generate the augmented speed, will be extinguished. There is, of course, no uncertainty about this proposition. Given the quantity of sediment discharged at the mouth of the river during a fixed period, or given the extent and depth of the delta of the Mississippi, and the specific gravity of its sedimentary matter, we can state with perfect accuracy the amount of retardation to be overcome by the earth every second, or the total amount of *vis viva* lost during the formation of the delta.

It has been already stated that the mean annual discharge of earthy matter at the mouth of the Mississippi is 903,100 millions of pounds. The centre of the basin, indicated on the diagram representing the earth, before alluded to, being 2,461,320 feet nearer the axis than the mouth of the river, we can readily calculate that the increase of rotary velocity will be, as already stated, 179 feet per second; a rate acquired by a fall through 500·6 feet. The elements are thus furnished for determining with precision the amount of *vis viva* which the earth must part with in consequence of the change of position of matter attending the abrasion during the flow of the rain water from the basin to the mouth of the river. Multiplying 903,100 millions by 500·6, we prove positively that the amount of energy to be given up by the earth in order to impart the stated incease of rotary velocity to the abraded matter, exceeds four hundred and fifty-two trillions of foot-pounds annually. But the formation of 30,000 square miles of delta, over which the Mississippi now runs, has required ages, during which the earth has been unceasingly deprived of *vis viva*. Computation is scarcely needed to show that unless some adequate counteracting force has been in operation, a perceptible diminution of the earth's axial velocity has taken place.

There is another point connected with the subject of retarding influence resulting from solar heat, which cannot be passed over, but which I approach with much diffidence—the question whether it can be shown that a sufficient compensatory force is acting to make good the immense amount of dynamic energy expended in imparting the increased rotary velocity to the *water which forms the vehicle of* the sedimentary matter in rivers running towards the equator.

The mean rate of discharge of the Mississippi into the Gulf of Mexico somewhat exceeds 38,600,000 pounds per second. We have already seen that the position of the centre of the basin is so far north of the outlet of the river as to place the latter 2,461,320 feet further from the axis of the earth than the former, and that this difference produces an increase of circumferential velocity so considerable that a fall through 500·6 feet is necessary to generate the same. The amount of *vis viva* of which the earth is being deprived *every second* by the waters of the Mississippi and its tributaries during their flow to the sea will accordingly be 19,323,000,000 of foot-pounds. As the mind cannot properly comprehend the magnitude of this force, let us reduce it to a standard with which we have become familiarized. A horse-power is 33,000 pounds raised one foot high in a minute, or 550 pounds raised one foot high per second. Dividing the before-stated total energy by this standard of 550, the important fact will be established that to make good the loss of *vis viva* which the earth suffers demands a constant expenditure of 35,133,000 horse-power.

What provision do we discover for making good this stupendous drag on the earth's rotation? The waters precipitated on the Mississippi basin come chiefly from the Gulf of Mexico, raised from its surface by the radiant heat of the sun. The gulf being situated *south* of the outlet of the river, the aqueous particles possess, at the commencement of the ascent, a greater circumferential velocity than the basin, and hence tend to impart motion to the atmosphere during their northerly course. On purely dynamic considerations, that motion and the motion of the aqueous particles ought to restore to the earth the loss of *vis viva* sustained, provided solar influence be not present. But solar influence *is* present; the atmospheric currents do not move altogether in accordance with static laws, but are controlled and perturbed by the heat of the sun, an *outside* force competent to disturb and destroy terrestrial equilibrium. Hence, we find that in place of an easterly motion of the atmosphere tending to restore, by its friction against the surface of the basin, the loss under consideration, the sun is frequently expending a vast amount of mechanical energy productive of currents which, by friction in a contrary direction, augments the loss. It would be futile to attempt a demonstration to *prove* that, owing to solar influence, the friction and other resistance called forth by currents of air and vapor, is inadequate to restore the loss of *vis viva* sustained by the earth in consequence of the increase of rotary velocity which it must impart to the waters of rivers running towards the equator. Nor would it be less futile to attempt a demonstration showing that the friction and resistance produced by such currents passing over the Mississippi basin from west to east, is sufficient to restore the expended force of 35,000,000 horse power exerted in an opposite direction. Those who imagine that Laplace's theory of compensation relative to atmospheric currents is applicable in this case, and who consequently will contend that the great disturbance which our figures have incontestably established corrects itself by the means discussed, will do well to reflect on the precarious nature, the obvious uncertainty of the forces relied upon to restore the lost *vis viva*.

RIVERS FLOWING TO POLAR SEAS.

Some allusion to the rivers which carry sedimentary matter toward the poles is called for before dismissing the subject. Let us consider the River Lena, for instance, which, takes its rise in the Yablonoi Mountains, in the eastern hemisphere, latitude 53 deg., and empties its waters in the Arctic Oceans, latitude 73 deg. 25 sec. Calculation shows that the effect of such a great difference of latitude will be that a pound of matter transferred from the source to the outlet of this river, demands an expenditure of dynamic energy represented by 3609 foot-pounds in order to extinguish the greater *vis viva* possessed at the commencement than that retained at the termination of the descent. The centre of the basin, situated as shown by the tables in latitude 60 deg. 55 min., rotates with a velocity of 304 feet per second faster than the outlet of the river, a rate acquired by a fall through 1444 feet. The basin of the Lena covers 814,800 square miles. Assuming that the annual precipitation reaches only thirteen inches and that the discharge at the mouth of the river is only 0·25, like Northern Mississippi, the force extinguished and consequently exerted in the direction of the earth's rotation will amount to 17,589,000,000 of foot-pounds per second—very nearly balancing the retardation caused by the waters of the Mississippi. But the waters of the Lena, unlike the great Southern river, do not directly enter a heated caldron, to be at once converted into vapor. The previously chilled masses of the Lena flow into the great polar refrigerator, and from thence are transferred to the evaporators in the equatorial regions. This transfer, evidently, cannot be effected without a considerable retreat from the earth's axis, so considerable, indeed, that before the required evaporation takes place, the waters are further from that axis than their source at the foot of the Yablonoi Mountains. Calculations are superfluous. The simple fact that the weight which imparted the motive force during the course toward the poles has, during the transfer to the evaporator, been removed to a greater distance from the axis of rotation, shows that the imparted *vis viva* of 17,589,000,000 of foot-pounds per second has become more than neutralized. Thus, we find that the waters of rivers flowing into the polar seas, although imparting a vast amount of mechanical energy in the right direction, cannot possibly restore any of the loss of the earth's *vis viva* occasioned by the waters of the Mississippi and other rivers discharging into the seas of the equatorial regions.

I now dismiss this subject, the consideration of which I have entered upon with so much diffidence, leaving it with those who deem Laplace's theory applicable to prove that the amount of *vis viva* which is imparted to the earth by the vapors condensed on the Mississippi basin, and not again evaporated on the same, is adequate to counteract the continually retarding force of 35,000,000 of horse power.

ABRASION BY THE FLOW OF RAINWATER.

Returning to the subject of abrasion and the retarding force indisputably exerted by sedimentary matter carried toward the equator, we have now to consider that branch of the subject which relates to the recovery of *vis viva* resulting from the lowering of the earth's surface by the abrasion caused by the flow of rain water. General Humphrey's official report of the Mississippi river shows that the annual discharge of sediment and earth (of a specific gravity of 1·93 or 120·8 pounds to the cubic foot) amounts to 7,474 millions of cubic feet. The Red river district of 97,000 square miles, drained by the Bayous Atchafalaya, Plaquemine and La Fourche, is not included in this amount, and hence the stated discharge is contributed by 1,147,000 square miles of basin. Each square mile accordingly yields up only 6516 cubic feet of earthy matter, and as this quantity would cover only 78,193 square feet of surface to the depth of one inch, it will be seen that the entire surface of the river basin only loses 1-356 part of an inch in depth per annum. This fact, established by a careful examination of a river basin which covers a considerable portion of the earth's surface, is one of profound interest. It enables us to determine with certainty that it will require 356 years to lower the surface of the Mississippi basin one inch, and that the mighty "father of waters" must toil for 4272 years to lower the entire surface a single foot.

The centre of this basin being only 500 feet above the level of the sea, the force tending to restore *vis viva* through the approach of the abraded matter towards earth's centre will be insignificant. The problem may be presented in a very simple form by stating that the diminution of circumferential velocity produced by an approach of 500 feet from the surface of the Mississippi basin towards the centre of the earth amounts to 0·0277 foot per second, a rate attained by a fall through 0·00001205 foot. Multiplying the weight of sediment discharged per annum, 903,100,000,000 pounds, by 0·00001205, we find that the energy to be extinguished, in other words, the force imparted in the direction of the earth's rotation, merely amounts to 10,881,451 foot-pounds per annum. This small and wholly inappreciable compensatory force is further reduced by the counteracting influence attending the elevation of the level of the ocean 1-49,955 of an inch annually consequent on the entering sedimentary matter, the formation of the delta.

Leaving out of sight this trivial elevation of the ocean level, and dividing the 10,881,451 foot-pounds *vis viva* restored by 452 trillion foot-pounds lost, it will be found that the approach of the abraded matter toward the centre of the earth scarcely recovers 1-41,000,000 part of the energy parted with during the change of position in the direction of the equator.

EFFECT OF THE WORKS OF MAN.

Another cause of retardation of the earth's rotation connected with solar influence remains to be considered, viz., that resulting from the exercise of human intelligence and human muscle, alike depending on solar influence.

The work of man has assumed such proportions already that it must for the future enter into all accurate calculations concerning the retardation of the axial velocity of the earth.

We may not be able to express by figures to what extent the ancient Egyptians by the exercise of their muscles increased the length of a day, yet close reasoning compels us to admit that the removal of thousands of millions of pounds to an increased distance from the axis of rotation during the erection of their pyramids, in some localities, caused a retardation, which, after the lapse of ages, will be marked by a later rising of the sun than if those pyramids had not been erected. At the present time, however, man, directed by superior intelligence, and calling to his aid various forces emanating from solar heat, is busy transferring matter from its original position on so large a scale that perceptible disturbance will be produced. A modern first-class city, it may be observed, weighs more than ten such structures as the "Great Pyramid," the building materials being almost invariably obtained from below the surface of the ground, and hence removed to a greater distance from the axis of rotation. In addition to the enormous masses of stone, and earth in the form of bricks, which are thus removed, we have to count the weight of iron and mineral coal raised from below the surface of the earth, amounting to billions of pounds annually. Let us bear in mind that any computation of the weight of human habitations and other structures which in course of time will be piled up above the surface of the earth, based on the present rate of increase, and upon the present habits and necessities of our race, would fall far short of the weight which will actually change position during the next and coming centuries by the hand of man. Unquestionably, before the earth shall have received its full complement of inhabitants, and man's intelligence shall have reached the climax, changes so extensive will have been made in the disposition of matter near the crust, that ordinary instruments for measuring will prove precise enough to give to the eye a conception of the extent to which the earth's centre of gyration has been disturbed by human interference.

Respecting the annexed tables, the following explanation will probably be deemed sufficient:—

The extent of the several river basins—136 in all—have been ascertained from the best maps extant. By reference to Plate XVI, showing the eastern part of the Mississippi basin, it will be readily understood in what manner their boundaries have been laid out. A line is drawn on the map dividing the territory equally between the source of each river and tributaries and those of adjoining basins. The boundaries being thus defined, the areas have been calculated in English statute miles, the latitude and longitude of the centre of each basin being determined at the same time.

By considering the earth as a perfect sphere, 7,921·41 miles in diameter, according to Sir John Herschel's determination, the calculations have been rendered extremely simple. This will be seen by reference to the sections of the earth, plate XVI, which contains all the elements for computing the rotary velocity of the centre of the river basins, and of the mouths of the rivers. These velocities are entered in the tables for each river basin, also the diminution of *vis viva* caused by the transfer of the sedimentary matter from the centre of the basin to the mouth of the river. It should be observed that owing to their trifling influence on the earth's rotation, and in order to save space, all the English and Scotch rivers' basins, whose sediment is transferred in the direction of the equator, have been entered together in the tables. The rivers of Ireland have also been entered together. It should, however, be understood that in computing the loss or gain of *vis viva*, each river basin has been calculated by itself; the amount entered being the result of the whole quantity of sediment transferred towards the equator. The area of basin entered in the table is accordingly the total. The river basins of Sweden and Norway, being very numerous and unimportant, have also in some districts been entered together in the tables, like those of Great Britain. Finally, the narrow coast districts, in both hemispheres, have been computed and entered in the table in a similar manner.

INDIAN RIVERS.

The quantity of sedimentary matter discharged by the Indus, Ganges, and Brahmapootra, being known with tolerable accuracy from actual observation, has not been computed according to standard furnished by the Mississippi, which is one pound of sediment per second for every 40·08 square miles of basin. Besides, local circumstances, such as the heated waters and profuse evaporation of the Bay of Bengal, and the close vicinity of the Himalaya Mountains, render the Ganges quite exceptional.

The discharge of earthy matter of the Ganges, entered in the tables, is, however, not so great as Sir Charles Lyell estimates in his "Principles of Geology." A brief explanatinn will show that those estimates are somewhat exaggerated. The quantity of matter carried down the Ganges at Ghazepoor being known, viz., 6,368,077,440 cubic feet annually, according to the observations and computations of Rev. Mr. Everest, we have only to ascertain with precision what area is drained by the river and its branches *above* Ghazepoor, in order to prove that Sir Charles Lyell has overestimated the source of the formation of the delta of the Ganges.

The maps of India being reliable, I have found it quite easy to define the extent of the basin drained by the part of the river under consideration, as well as that drained by the lower part and its branches; likewise the area drained by the Brahmapootra and its tributaries.

The basin of the Ganges, above Ghazepoor, contains, agreeable to accurate determination, 187,100 square miles. The basin below Ghazepoor contains 237,200 square miles, and that of the Brahmapootra 379,000 square miles. The quantity of matter which passes Ghazepoor being, as indicated by the total amount already stated, at the mean rate of 201·76 cubic feet per second, we might show by analogy that the mean discharge of the lower part of the Ganges should be 255·78 cubic feet per second; but Sir Charles Lyell states that the abrasion of the river and its tributaries below Ghazepoor is greater than above. This may be so as regards the Gogra, Gunduk, Khosee, and Teesta, which descend from the mountains; but the southern tributaries, and especially the lower part of the main stream, which runs with a continually decreasing speed, cannot possibly cause an abrasion greater than the Ganges above Ghazepoor and its many tributaries descending from the Himalaya. If, therefore, we admit that the basin below Ghazepoor contributes proportionably 50 per cent. more earthy matter than above that place, our estimate will certainly be in excess of the real fact. The Ganges below Ghazepoor, the basin of which, as stated, is 237,200 square miles, will consequently discharge 382·67 cubic feet per second. The Brahmapootra, assumed by Sir Charles Lyell to carry down proportionably the same amount of matter as the Ganges above Ghazepoor, having a basin of 379,000 square miles, will contribute 408·71 cubic feet per second. Adding the contribution of Upper Ganges before specified, the total quantity of earthy matter discharged into the Bay of Bengal will be 994·14 cubic feet mean rate per second, or 31,373,248,851 cubic feet per annum. The estimated quantity of 40,000,000,000 cubic feet per annum named in the Principles of Geology will thus be found inconsistent with the data on which it apparently is founded. The annexed tables, it need hardly be stated, contain the quantities determined by the foregoing estimates, based on a specific gravity of 1·93 for the sedimentary matter in a dry state and upon the areas of the basins specified.

AFRICAN AND OTHER RIVERS.

Respecting the African rivers, none of which have been entered in the tables, it will suffice to state that they have no material influence on the earth's rotation, from the fact that the two principal rivers, the Nile and the Niger, flow in opposite directions—the former towards the pole and the latter towards the equator. There is, however, considerable difference of latitude in favor of the Nile; but this cannot be far from balanced by the greater quantity of sedimentary matter brought down by the Niger, as proved by its delta of 240 miles of coast. The general course of the other important rivers of Africa, the Senegal, Zambesi, and Orange rivers, is so nearly parallel with the equator that they exercise no appreciable influence on the axial rotation of the earth.

Australia being drained by rivers the course of which are directed to all points of the compass, and, consequently, of no account as regards the earth's motion, has likewise been excluded from the tables. It may be observed that the basin of the important river Goolwa and its tributaries, excepting the Callewatta, is almost on the same parallel with the mouth of the main river. Hence scarcely any disturbing force is produced, notwithstanding the great extent of the basin drained by the Goolwa. The Amazon, which drains more than two millions of square miles, strikingly illustrates the feeble influence of rivers the centres of whose basins are nearly on the same parallel as their outlets, more particularly when, like the Amazon, they are situated near the equator. It will be seen by reference to the tables that the enormous masses of solid matter carried to the ocean by the greatest river on the globe deprives it of only 70,000 foot pounds per second.

CONCLUSIONS.

It need hardly be stated that owing to the existing uncertainty regarding the amount of precipitation in the higher latitudes, not to mention our total want of information as to the proportion of sedimentary matter conveyed, especially with reference to the great Asiatic and North American rivers, no perfect table can be prepared at present, or any reliable calculations made to determine the amount of *vis viva* restored to the earth by the rivers flowing to the poles. But this uncertainty about the precipitation in the polar regions, and the quantity of solid matter discharged into the Arctic Seas, does not in the least invalidate our estimate of the magnitude of the retarding influence on the earth's axial rotation, caused by the numerous rivers flowing towards the equator. Indeed, the standard furnished by the abrasion occasioned by the waters of the Mississippi, viz., one pound of solid matter per second transferred to the mouth of the river for every 40·08 square miles of river basin drained, will be found rather below than in excess of the general average of other rivers running in the direction of the equatorial regions. Hence no reasonable doubt can been tertained that the earth as shown, by the tables, sustains a loss of *vis viva* of 39,894,658 foot pounds *every second*. Multiplying this sum by 86,400 seconds, we learn that every succeeding day marks a diminution of the earth's *vis viva* of 3,446,898,451,200 foot pounds, in consequence of the change in position of the abraded matter carried towards the equator.

Future investigations must determine to what extent this loss is reduced by the counteracting influence of the abraded matter which is carried in the direction of the poles.

In the meantime, the magnitude of the retarding force which we have indisputably established by our calculations and tables, compels us to admit that constancy of rotation of the earth is incompatible with solar influence.