which are the spider monkeys, the howlers, and the marmosets, are found in the Neotropical region, except in its southern and western parts. The lemurs are mostly confined to the island of Madagascar, some few inhabiting Eastern India, and two forms occurring in Western Africa.

Among the large order of the Carnivora the lion is a denizen of the forests of the Ethiopian region, and spreads slightly beyond it into India. The tiger is found in the Indian region, and spreads up into China and Central Asia, where its coat becomes coarser in texture. The leopard is distributed over the districts of the lion and tiger; it is also found in Borneo and Ceylon, whilst the lynx occurs in the Neartic and Palæarctic regions. The dogs are cosmopolitan, though it is doubtful whether the single form of Australia has not been introduced by man in early times. The bears inhabit the Palæarctic, the Nearctic, and the Indian regions, being also found in the Andes of Peru.

Among the odd-toed, or Perissodactylate Ungulates, the horses and asses are strictly Old-World forms, the exact place of origin of the former being uncertain. The asses are spread over the Indian and Ethiopian regions. The tapir is very aberrant in its distribution, one species appearing only in Sumatra and the Malay Peninsula, while in the northern portion of South America and Central America three others occur. The rhinoceroses are from the Indian and Ethiopian regions only, the Asiatic species all being now or having lately been exhibited in the Zoological Gardens. Those from Africa are less perfectly known, only two species having been accurately determined.

Among the even-toed, or Artiodactylate Ungulates, the camels are very peculiar in their habitats, the Llamas of the Andes and the camels of Africa, Arabia, and part of Russian Asia being the only known forms; those from the last-named locality being the only known wild true camels of the present day. The giraffe is purely Ethiopian. The bison in North America represents the oxen of the Indian region, which in Africa and Arabia are in great measure replaced by the antelopes, so varied in form and size. The Cervidæ are not found in the Ethiopian nor Australian regions. The hippopotamus inhabits all the large rivers of Africa, the smaller species being found in and about Liberia. Of the Swine-family the peccaries are the representatives in the Neotropical region, whilst the quaint Wart-Hog and Red River Hog are exclusively African.

The hyrax, or coney of Scripture, whose zoological position is so uncertain, is found in Arabia and parts of Africa only.

There are only two species of elephant known, the Indian being from the Indian region, and the African from the Ethiopian. In very recent times they abounded in Siberia, and earlier still in many other parts of the world.

The Neotropical region abounds in peculiar Edentate animals, as the armadillos, sloths, and ant-eaters. The scaly ant-eaters or Pangolins, and the ant-bears or Orycteropus, are found, the former in India and Africa, the latter in Africa only.

Among the Insectivora, the peculiar Solenodon inhabits St. Domingo; the gilded mole, South Africa; the Tenrec, Madagascar; and the Tupaias, the Malay districts.

Among the Rodentia the porcupines, divided into two well-distinguished sub-families, inhabit, one the Old and the other the New World. The Neotropical region, however, is the head-quarters of the *Hystricidæ*; the capybara, together with the agoutis, and numerous other forms being from that locality. There are also found the chinchilla and viscacha. The beaver abounds in the Nearctic region, and used to do so in Europe, till the increase of population has almost exterminated it. The hare and rabbits have a wider distribution, as have also the squirrels.

It will be noticed that Australia has been scarcely mentioned in the above remarks, and that the dog which is spoken of in connection with it is not known certainly to be indigenous. This is because the mammalian fauna is almost entirely represented by animals of the Marsupial order, the kangaroos, bandicoots, phalangers, wombat, koala, thylacine, and dasyures being peculiar to it and Van Dieman's land. Among Marsupialia the group of opossums is only found in the Neotropical region, extending quite through Mexico into the United States.

The Monotremata, including only the duck-bill or ornithorhynchus and the echidna, are confined to New South Wales and Tasmania.

(To be continued.)

THE FLUCTUATIONS OF THE AMERICAN LAKES AND THE DEVELOPMENT OF SUN-SPOTS

IN the course of an investigation, undertaken in my capacity as Geologist to the B.N.A. Boundary Commission, as to late changes of level in the Lake of the Woods, bearing on the accuracy of certain former surveys, I found it desirable to tabulate the better-known fluctuations of the great lakes for a series of years as a term of comparison. The observations of secular change in Lake Erie are the most complete, and these, when plotted out to scale, showed a series of well-marked undulations which suggested the possibility of a connection with the eleven-yearly period of sun-spot maxima. A comparison with Mr. Carrington's diagram of the latter confirmed this idea, and as I do not remember to have seen these phenomena connected previously, I have been induced to draw out the reduction of both curves here presented, and the table of the height of water in the lakes.

The changes of level affecting the great lakes are classed as follows by Colonel Whittlesey, who has given much attention to the subject:—

1. General rise and fall, extending through a period of many years, which may be called the "Secular Variation."

2. Annual rise and fall within certain limits, the period of which is completed in about twelve months.

3. A sudden, frequent, but irregular movement varying from a few inches to several feet. This is of two kinds, one due to obvious causes, such as winds and storms; another, described as a slow pendulum-like oscillation, has been somewhat fully discussed by Whittlesey in a paper read before the American Association at its last meeting, and is due probably to barometric changes in the superincumbent atmosphere.

The first class is the only one directly included in the present inquiry.

1.—*Table of Great Lakes.*—In Mr. Lockyer's new work on Solar Physics, chap. xxvi., entitled "The Meteorology of the Future," exhibits the parallelism of periods of solar energy, as denoted by the outburst of sun-spots, with the maximum periods of rainfall and cyclones, and for the southern hemisphere, by a discussion of his own and Mr. Meldrum's results. In the table (p. 505) I have arranged the more accurate numerical observations of the height of the lakes from registers kept for the last few years, in a method similar to that there adopted.

Prof. Kingston's observations of Lake Ontario were taken at Toronto, and measured upward from an arbitrary mark. They extend from the year 1854 to 1869, and include the minimum periods of 1856 and 1867, and the maximum of 1860. Taking the mean annual level for

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each minimum and maximum epochal year, and one year on each side of it, as is done by Mr. Meldrum, and deducing a mean from each of three tri-yearly periods,

Table showing the height of water in the American Great Lakes, measured upward from an arbitrary mark, for the years surrounding periods of maxima and minima in the occurrence of Sun-spots.

Sun-spot Periods.	Year.	Lake Ontario, from Prof. Kingston's observations. Yearly means.	Lake Ontario, from Prof. Kingston's observations. Tri-yearly means.	Lake Ontario, from U.S. Lake Survey Observations. Yearly means.	Lake Ontario, from U.S. Lake Survey Observations. Tri-yearly means.	Lake Superior, from U.S. Lake Survey Observations. Yearly means.	Lake Superior, from U.S. Lake Survey Observations. Tri-yearly means.	Lake Michigan, from U.S. Lake Survey Observations. Yearly means.	Lake Michigan, from U.S. Lake Survey Observations. Tri-yearly means.	Lake Erie, from U.S. Lake Survey Observations. Yearly means.	Lake Erie, from U.S. Lake Survey Observations. Tri-yearly means.
Min.	1855	17·8	21·7								
	1856	20·6									
	1857	27·5									
Max.	1859	28·6	24·7	30·48	28·80	40·32	33·12	29·88	25·92	33·60	30·60
	1860	18·3		22·68		30·24		23·76		28·32	
	1861	27·4		33·12		28·26		23·88		29·76	
Min.	1866	9·3	11·2	18·36	19·20	18·12	18·84	3·72	5·28	17·76	16·56
	1867	19·7		28·86		20·16		7·68		18·00	
	1868	4·6		13·68		18·24		4·32		13·80	

Mean of maximum periods in Lakes Ontario, Superior, Michigan, and Erie, from U.S. Lake Survey Obs. 29·61
Mean of minimum " " " " " 14·97
Difference 14·64

The measurements are in inches and decimals.

the agreement is close between the solar periods and those of fluctuation in the lakes.

The remaining observations are those of the U.S. Lake Survey, and include only one period each of maximum and minimum in solar spots. The measurements of the U.S. Survey are reckoned *downwards* from a mark representing the high water of 1838 in each of the lakes, but in the table here given they have been reduced so as to read upwards from an arbitrary line chosen 4 feet below that datum. They are thus rendered more intelligible and made to agree in sense with Prof. Kingston's measurements.

The result is the same in each of the lakes, only differing in amount by a few inches. A mean deduced from the U.S. Lake Survey observations in Lakes Superior, Michigan, Erie, and Ontario, gives a difference between the years surrounding the maximum of 1860 and the minimum of 1867 of 14·64 inches in favour of the former.

2. *Diagram of Curves.*—The curve representing the fluctuation of Lake Erie from 1788 to 1857 inclusive is constructed on a careful discussion of the evidence collected by Col. Whittlesey and given by him most fully in the "Smithsonian Contributions to Knowledge" for 1860.

From 1788 to 1814 there are no accurate measurements to any well-recognised datum line, and I therefore give below the measurements and approximations on which the general curve for these years has been constructed. The description of the fluctuation of the lake will be seen in many cases to apply with verbal accuracy to the sun-spot curve.

"1788—1790. By tradition derived from the early settlers very high; according to some as high as 1838, but this is doubtful.

"1796. By the first emigrants and surveyors reported as very low—5 feet below 1838.

"1797. Rising rapidly.

"1798. Water continues to rise, but 3 feet below June 1838.

"1800. Very high; old roads flooded.

"1801. Still high.

"1802. Very low; reported by old settlers as lower than 1797.

"1806. Very low; reported by old settlers as lower than 1801—2, and declining regularly to 1809—10 when it reached a level by many considered as low as that of 1819.

"1811. Rise of 6 inches in the spring over 1810, by measurement, and a fall of 2 inches.

"1812. Rise of 14 inches in spring over 1810, by measurement, and a fall of 3 inches.

"1813. Rise of 2 feet 2 inches in spring over 1810 by measurement.

"1814. Rise of 2 feet 6 inches in spring above general level of 1813."

From 1815 to 1833, both inclusive, occasional measurement to fixed data exist; the supplementary notes are here given.

"1815. Rise of 3 feet above average level of 1814. (This statement is not confirmed by an actual measurement made in August, and is probably exaggerated).

"1816. Water still high, but falling, and continued to fall till 1819.

"1819. Lowest well-ascertained level of the waters in Lake Erie.

"1820. Stated to be in August as low as 1819.

"1821. Rising.

"1822. Rising; in the spring 4 feet below June 1838.

"1823. Rising; in the spring 3 feet 3 inches below 1838.

"1824. Rising gradually.

"1825. Rising; lowest level 3 feet below June 1838.

"1826. Rising; lowest level 2 feet 10 inches below June 1838.

"1827. About the general level of 1815.

"1829. Water still rising.

"1830. General level same as 1828.

"1831. Lower than last year; yearly change at least 3 feet.—Col. Whiting. (Probably an error as this would place the water unprecedentedly low. Col. Whiting probably ascertained that the lake was falling and erred in taking some former high-water mark for that of the preceding year).

"1832. General average 2 feet 10 inches below June 1838.

"1833. General average 3 feet 2 inches below June 1838."

From this date to 1857 many actual measurements are given by Whittlesey, and from these the curve for those years has been constructed. The whole of the observations are reduced as nearly as possible to the average level for each year by comparison with a mean annual curve for about 10 years constructed from monthly averages of bi-five-day means given by the U.S. Lake Survey. 1859 to 1869 both inclusive are from yearly means derived from continuous observations at Cleveland by the U.S. Survey. 1871 to 1873 are from information kindly furnished by Gen. Comstock, Director of the Lake Survey. I have no data for 1870.

The earlier and less systematic observers of the fluctuations of the lakes would scarcely give attention to any but the more important changes of level, and it is possible that these in many cases may have been exaggerated in amount. It would seem improbable, however, from the

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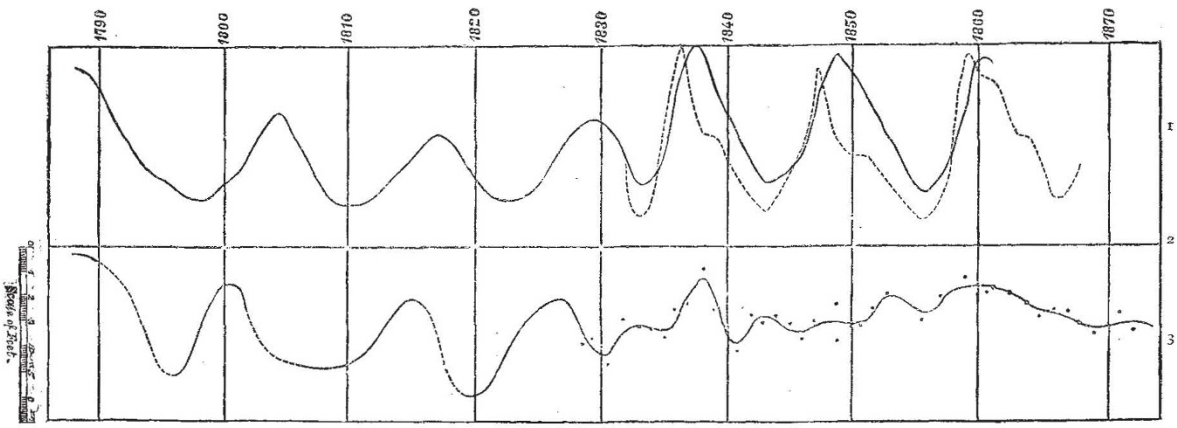
number of observations which have come down to us, that any variations of importance have escaped notice.

In the upper part of the diagram, the unbroken line represents Carrington's curve founded on the number of sun-spots. The broken line is a reduction of a mean curve based on the area of the spots given by De la Rue, Stewart, and Loewy in the Philosophical Transactions for 1870; and is introduced as showing the solar periods to a later date.

3. *General Remarks.*—The first four maxima of sun-spots represented in the table being separated by long intervals of years with few spots, and not being very intense, would appear to have been closely followed by L. Erie. More especially 1837, the year of greatest known intensity according to both spot curves (333 new groups of spots according to Schwabe), was marked in its effects on the lakes, giving rise in 1838 to the highest recorded level of the waters in Erie and Ontario, and probably also in Superior, though here the data are not so certain. The high-water mark of 1838 has since been employed as the datum to which all the measurements of the Lake Survey are reduced.

The three last periods of maxima of sun-spots are extreme, and the intervals characterised by their deficiency so short that the lakes seem to have been unable to follow them as closely as before. One period of high water being to a great extent merged in the next, and resulting in a general high state of the lakes for the last thirty years, which may be connected with the Wolfian Cycle of fifty-six years in the development of sun-spots. The lakes do not seem to have responded to the maximum of 1848, but by a reference to the curve of area of sun-spots, it will be seen that the intensity of this period was not so great as of those on either side of it, and the period of maximum was maintained for a very short time only. The important sun-spot maximum of 1859-60 was evident in its effect on the lakes even at their present general high level. With regard to the Lake of the Woods the data are slight, but it may be mentioned that this lake is known to have been very low in 1823, and in 1859 to have attained a point which it has never touched since, and which is about 3 feet higher than the present level. The lake is also known to have been for a good many years higher than usual, and at least one well-marked high water took place between 1823 and 1859, which may very probably have been synchronous with that of 1838 on the great lakes.



Comparative Diagram of the Fluctuations of Lake Erie, and Periods of greater or less Solar Activity as indicated by the occurrence of Sun-spots. 1. Solar Spot Curves. 2. High Water, June 1838. 3. Lake Erie.

This lake derives its water from the western slope of the same Laurentian range which feeds Lake Superior.

The correspondence between the periods of maxima and minima in solar-spot cycles and in the fluctuation of the great lakes, though by no means absolute, seems to be sufficiently close to open a very interesting field of inquiry, and to show the extension of the meteorological cycle already deduced by Messrs. Meldrum and Lockyer for oceanic areas in the southern hemisphere, to continental ones in the northern.

The great lakes in their changes of mean yearly level probably show a very correct average of the rainfall over a large area, and thus indicate the relative amount of evaporation taking place in different seasons. It is to be observed, however, that the actual mean annual outflow of the lakes would be a better criterion, and that from the form of the river valleys giving exit to the waters, this must necessarily increase in a much greater ratio than the measured change of level in the lake itself. It is much to be desired that such observations should be systematically made. The occurrence of seasons of great activity of evaporation and precipitation, as indicated by the lakes synchronously with those of maximum in solar-spot production, would tend to confirm the opinions previously formed as to the coincidence of the latter with periods of greater solar activity. Wolf, as quoted by Chambers, states from an examination of the Chronicles of Zurich, "that years rich in solar spots are in general drier and more fruitful than those of an opposite character, while the latter are wetter and stormier than the former." Gautier, from a more extended series of observations, including both Europe and America, has deduced an exactly opposite conclusion, which, from the evidence of the great lakes, would appear to be the correct one.

It is quite possible, however, that both may be true (see "Solar Physics," p. 430). The great lakes lying at the base of the Laurentides, where moisture-bearing winds from the southward and westward are interrupted in their course, and meet with cold currents journeying over these hills from the north, are essentially in an area of precipitation, and greater precipitation would here be the natural result of greater solar energy. In other regions excessive evaporation may result from the same cause, and this may account for the gradual desiccation which on the authority of many observers is going on at present over great areas of the inland plains of the west.

The observations here given cannot be accepted as conclusive, but derive additional importance from the large area which they represent, and may suggest more systematic investigation of the subject, and the accumulation of accurate observations, which in the course of years may lead to results of greater value.

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