$k\frac{\delta t}{\delta p} \div \frac{dv}{dt}$ is the smaller of the two, and we proceed to find its value. We have as a first approximation to the behaviour of gases,

$$pv = C(1 + \alpha T),$$

where T is the temperature centigrade on a gas-thermometer.

We therefore have, as approximate equations,

$$v = \frac{C}{p}\left(1 + \alpha T\right),$$

$$\frac{dv}{dT} = \frac{C\alpha}{p}.$$

We may further assume that $\frac{dv}{dt} = \frac{dv}{dT}$, since the degrees are practically equal on the two scales.

We therefore obtain, approximately,

$$v = \frac{C}{p}\left(1 + \alpha T\right),$$

$$\frac{dv}{dt} = \frac{C\alpha}{p}.$$

Using these approximate values, we have

$$k\frac{\delta t}{\delta p} \div \frac{dv}{dt} = \frac{kp}{C\alpha}\frac{\delta t}{\delta p}$$

$$= \frac{k}{C\alpha}\frac{\delta t}{\delta \log p},$$

and the equation for t becomes

$$t = v \div \frac{dv}{dt} + \frac{k}{C\alpha}\frac{\delta t}{\delta \log p}.$$

If now, further, we use the approximate values of v and $\frac{dv}{dt}$ in the term $v \div \frac{dv}{dt}$, we shall obtain

$$t = \frac{1}{\alpha} + T + \frac{k}{C\alpha}\frac{\delta t}{\delta \log p}.$$

This is the formula usually given.

This method of working appears to me to be incorrect, for the following reason:—

In the equation

$$t = \left(v + k\frac{\delta t}{\delta p}\right) \div \frac{dv}{dt}$$

there are two terms on the right-hand side, one of which, $k\frac{\delta t}{\delta p} \div \frac{dv}{dt}$, is small compared with the other. We may therefore neglect it as a first approximation, and we then obtain $\frac{v}{t}$ = function of p, in accordance with the laws of a perfect gas. If we wish to proceed to a closer approximation, we may use the perfect-gas laws as sufficiently good in the term $k\frac{\delta t}{\delta p} \div \frac{dv}{dt}$, because that is a small term, and the departure of the actual gas from the perfect gaseous laws will consequently in this term introduce only errors which depend on the squares of small quantities. But we are not at liberty to use the perfect gas laws in the remaining term $v \div \frac{dv}{dt}$, because it is *not* a small quantity, and we have therefore no guarantee that the use of such an approximation will not introduce errors of the first order of small quantities—that is to say, comparable with the term $k\frac{\delta t}{\delta p} \div \frac{dv}{dt}$ itself. With such errors introduced, the second approximation would not necessarily be better than the first.

The mistake in principle, which I have indicated, appears to be widespread, since it has crept into several of our well-known text-books. Thus the discussions given in Tait's "Heat" (pp. 338–339), in Baynes' "Thermodynamics" (pp. 126–127), and in Maxwell's "Heat" (pp. 211–214), all appear to me infected by this source of error. It is true that in these discussions the mistake is introduced more subtly, and is covered with a mass of symbols; whereas in the faulty investigation given above, I have purposely made the paralogism as glaring as possible. But *in substance* the mistake occurs in each of the discussions above named. JOHN ROSE-INNES.

May 13.

Printer's Ink and Photographic Plates.

IN a paper on the action exerted by certain metals and other substances on a photographic plate, by Dr. W. J. Russell (*Proc. R.S.*, vol. lxi. p. 424), the author mentions that the *Westminster Gazette* is printed with an ink which readily acts on a photographic plate. The printed paper in some experiments is placed in contact with the photographic plate, in the dark, and after being left in contact for some time, in the dark, the plate is developed, and the printed letters come out clearly. Dr. Russell mentions the names of several periodicals the print of which acts on a sensitive plate. To these the following example of the same phenomenon may be added: a photographic plate wrapped up in an advertisement sheet of *Modern Society* on development showed the printed characters very clearly, the words reading from left to right, not being reversed, so that the action must have taken place through the thickness of the paper. This sample of the action of printer's ink on a photographic plate (the property of Mr. W. B. Croft) has been in the excellent physical laboratory museum at Winchester since 1892. The print is good and clear, and probably one of the earliest observed instances of the action of printer's ink on a photographic plate in the dark, in which the physical conditions were known and recorded. F. J. JERVIS-SMITH.

Oxford, May 16.

Heavy Rainfalls.

I THINK it worthy of record that at a place called Nedunkeni, in the Northern Province of Ceylon, the rainfall on December 15–16, 1897 (24 hours), was 31·76 inches. The average annual rainfall of this place was 64·70, but in 1897 the amount totalled 121·85 inches.

The heaviest recorded rainfalls (as given in the "Encyclop. Britt.") are at Joyeuse, France, 31·17 inches in 22 hours; at Genoa, 30·00 inches in 26 hours; at Gibraltar, 33·00 inches in 26 hours; on the hills above Bombay, 24 inches in one night; and on the Khasia Hills, India, 30·00 inches on each of five successive days.

The rainfall in Ceylon, referred to above, is therefore notable. The greatest annual rainfall occurs, as is well known, on the Khasia Hills, with 600 inches. The wettest station in Ceylon is Padupola, in the Central Province, with 230·85 inches (mean of 26 years), the rainfall for last year being 243·07 inches. C. DRIEBERG.

School of Agriculture, Colombo, Ceylon.

Hermaphroditism in the Apodidæ.

I AM not sure but that the tone of Prof. Lankester's demand, in NATURE of May 12, that I should "at once" withdraw my "assertions," or confirm them by "some evidence," would not have justified my ignoring it altogether. For those of your readers, however, who may be interested in this subject, may I say that I *have* produced "some evidence" (*Ann. and Mag. Nat. History*, xvii., 1896, plates xi. and xii.), and no counter evidence whatever has yet been forthcoming to shake my faith in the justness of my conclusions. HENRY BERNARD.

Streatham, May 17.

MAGNETISM AND SUN-SPOTS.

WHEN Sir Edward Sabine was preparing his paper[1] "On Periodical Laws discoverable in the mean effects of the larger Magnetic Disturbances—No. ii.," in which he discussed the magnetic observations made at the temporarily established Colonial observatories at Toronto and Hobarton, he found that there existed at these places, in the years 1843 to 1848, a progressive increase in amount both of magnetic disturbance and in extent of diurnal range of the declination magnet, the values of diurnal range for the year 1843 having become in 1848 increased by some 40 per cent., the Toronto values for these years being 8′·90 and 12′·11 respectively, and the Hobarton values 7′·66 and 10′·63. This was an altogether unlooked-for result, one that engaged his special attention, such increase of value from year to year

[1] Read before the Royal Society, May 6, 1852.

in two quarters of the globe so widely separated as Toronto and Hobarton presumably indicating not simply a local effect, but one rather of cosmical character. He pointed out that as the sun must be recognised as at least the primary cause of all magnetic variations that conform to a law of local hours, as does the solar diurnal range, it seems not unreasonable to suppose that in the case of other magnetic variations we should look, in the first instance, to any periodical variation by which the sun is affected, to ascertain whether any coincidence of period or epoch is traceable. And he draws attention to the circumstance that, according to Schwabe's then recently-published table of frequency of solar spots, a minimum in number of spots occurred in 1843 and a maximum in 1848, with progressive increase in the intermediate years similar to that of the diurnal magnetic range during the same interval as shown by the Toronto and Hobarton observations. This led Sabine to infer the probable existence of a periodical variation in magnetism similar to that—one of about ten years—which Schwabe had detected in sun-spots from observations extending over a period of twenty-five years.

In the meantime another worker had been busy with the same subject. In *Poggendorff's Annalen* for December 1851 there appeared the well-known paper by Dr. Lamont, "on the ten-yearly period," in which he gave the following values of diurnal range of the declination magnet as observed at Munich.

1841 = 7·82	1846 = 8·81
1842 = 7·08	1847 = 9·55
1843 = 7·15	1848 = 11·15
1844 = 6·61	1849 = 10·64
1845 = 8·13	1850 = 10·44

Lamont considered that these numbers indicated a periodical variation, and from them he found by graphical construction that a minimum apparently occurred in 1843 and a maximum in 1848. He further discussed such older magnetic observations as were found to be available, and came to the following conclusion, which it may be interesting to give in his own words. "Die grösse der Declinations-Variationen hat eine zehnjährige Periode, so zwar, dass sie mit regelmässigen Uebergange fünf Jahre im Zunehmen, und fünf Jahre im Abnehmen begriffen ist."

Sabine became acquainted with Lamont's paper whilst writing his own, and quotes Lamont's figures from 1843 to 1848, showing how the Munich results confirmed those of Toronto and Hobarton. It would seem that Lamont and Sabine each independently suspected the existence of a periodical variation in diurnal magnetic range, which Lamont appears to have first distinctly formulated in the words quoted; whilst it was to Sabine that the suggestion that the periodical variation was one apparently concurrent with that of sun-spots was due. Lamont considered the variation to be so real that in any theory of the diurnal movement it could not be disregarded. Sabine more cautiously wrote: "As the physical agency by which the phenomena are produced is in both cases unknown to us, our only resource for distinguishing between accidental coincidence and causal connection seems to be *perseverance in observation*, until either the inferences from a possibly too limited induction are disproved, or until a more extensive induction has sufficed to establish the existence of a connection, although its precise nature may still be imperfectly understood." In a postscript to Sabine's paper (dated May 24, 1852) he gives a table of mean diurnal range of declination for Toronto and Hobarton from 1841 to 1851, which clearly shows, as do the Munich numbers, the minimum of 1843 and the maximum of 1848; and in 1856 he showed that at Toronto, from 1844 to 1848, there was a progressive increase in the amount of magnetic disturbance in all three elements of declination and horizontal and vertical force.

Considering that the periodical variation of diurnal range was found to exist in regions of the earth so far apart as Toronto, Hobarton and Munich, the results at the three places being distinctly corroborative, and, further, the circumstance that it appeared to be closely in accord with the established solar-spot variation, it seems to be matter for reflection as to how it happened that in some quarters the agreement between the magnetic and solar variations was thought to be only of apparent or accidental nature. Sir George Airy, in his paper[1] "On the Diurnal Inequalities of Terrestrial Magnetism," had occasion to give therein a list of the days of greater magnetic disturbance at Greenwich in the years 1841 to 1857, and he incidentally remarks that "there is no appearance of decennial cycle in their recurrence." But this is not surprising, for although magnetic disturbance does cluster about the epochs of maximum of sun-spots, it is on occasions by no means closely confined thereto, though nearly or quite absent at epochs of minimum of sun-spots. Thus the periodical variation, as regards the disturbance element, although existing, is not so distinctly traceable unless longer periods are examined, accompanying sun-spot maxima as disturbance does in a somewhat loose fashion as compared with the more regular increase and decrease of diurnal magnetic range with variation of sun-spot frequency. The behaviour of magnetic disturbance in this respect is indeed a matter that I am yet hoping to investigate more exactly.

Then, again, Lamont appears to have adopted for the diurnal magnetic range the difference between the positions of the magnet at 8h. in the morning and 1h. in the afternoon, as being the times of the greatest easterly and westerly deviation respectively. It is true that the positions of the magnet at these hours would not be likely to represent the extreme positions at Munich throughout the year, especially as regards the easterly deviation; still the diurnal range resulting from the employment of such fixed hours approximates in such degree to the true range for Munich, as very well serves clearly to bring out the decennial variation, of which indeed the good agreement between Lamont's and Sabine's results is of itself further proof, since the latter do depend on observations extending through the twenty-four hours of the day. From whatever cause, however, there were those in earlier days who doubted the existence of any real relation between magnetic and solar variations. The so-called decennial period, it may be here mentioned, seems to be more nearly an eleven-year period, this being about the mean value, although it is variable in length to the extent of several years.

When, in the year 1875, I was transferred at the Royal Observatory from the Astronomical to the Magnetical and Meteorological Department, I had then paid no particular attention to this question, and had an open mind thereon. But the daily examination of the photographic records after a time convinced me that change was in progress in the character of the records from year to year, such as even in this simple daily inspection of the records could not be well overlooked; and acting involuntarily on Sabine's principle of perseverance in observation, I came to the conclusion that it would be well to endeavour further to investigate the facts of observation, especially as the long series of Greenwich observations, made throughout on the same general plan and with instruments of the same kind, furnished so excellent an opportunity for applying an independent test of the reality or otherwise of the relation supposed to exist, which the late Dr. Wolf, of Zürich, had already done so much to establish. My first paper appeared in the *Philosophical Transactions* for the year 1880, and deals with the Greenwich observations from 1841 to 1877. This I have recently supplemented by a second paper, read before the Royal Society on March 10 of the

[1] Read before the Royal Society, April 23, 1863.

present year, which appears in the *Proceedings* of the Society. The results here employed extend from 1841 to 1896, a period of fifty-six years. The addition of the more recent observations is especially interesting as contrasting in some respects with the earlier portion, the

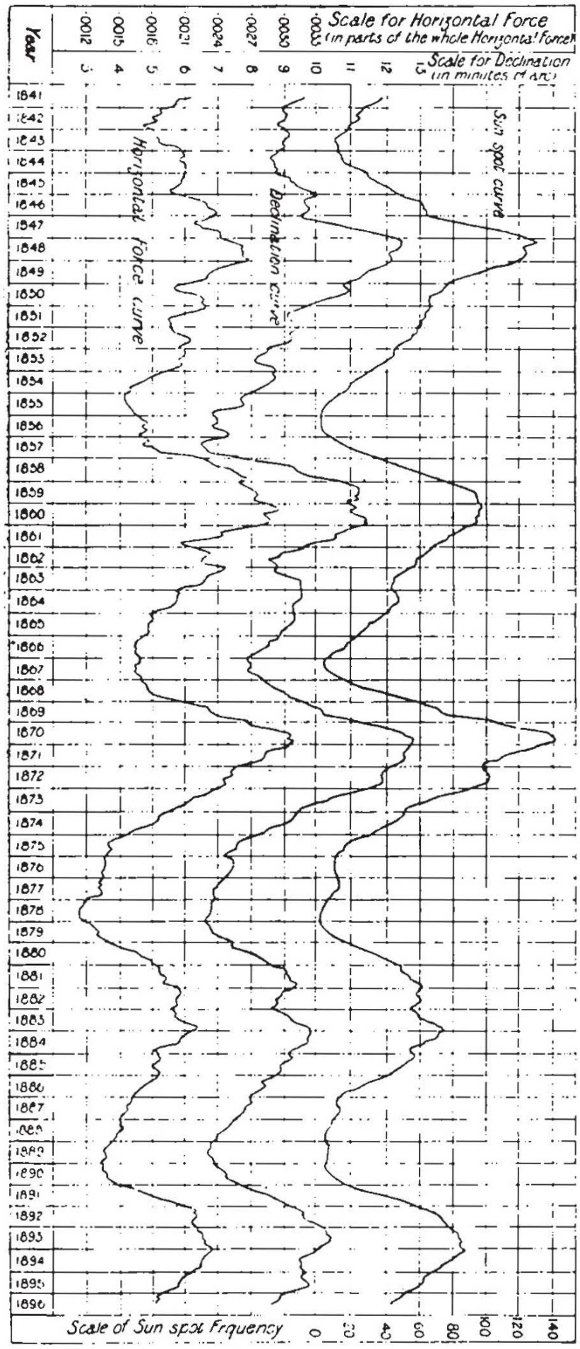

FIG. 1.—Smoothed curves of sun-spot frequency (Wolf). compared with corresponding curves showing the variation in diurnal range of the magnetic elements of declination and horizontal force from observations made at the Royal Observatory, Greenwich.

whole forming one continuous chain of evidence that much strengthens the argument for relation between the two classes of phenomena. The records of horizontal magnetic force, as well as those of declination, are employed From 1841 to 1847 the results depend on eye observations made at intervals of two hours. In 1848 and afterwards, they depend on hourly tabulations from the photographic records. The mean diurnal range in each month is taken to represent (relatively to other months) the magnetic energy of the month. By the mean diurnal range of declination or horizontal force is to be understood the difference between the least and the greatest of the mean hourly values in each month.

In any graphical representation of unexplained phenomena it is important to give ready reference to the numerical data employed. Consequently in both papers complete tables of the elements used are either included, or indication given where such collected results can be found. The numbers for declination are in minutes of arc, those for horizontal force are in parts of the force, taken as unity. There being in the numbers a strongly marked annual period (the summer values being greater than those for winter), numbers that shall be free of annual inequality have (as explained in the paper) been prepared and used to construct the middle and lower curves of the diagram of collected curves. For sun-spot frequency the numbers published for so many years by Dr. Wolf, and since his death continued by his successor, Prof. Wolfer, have been employed. It is impossible to value too highly work of this kind, carried on for so many years on one fixed plan; such steady adherence to a definite method having many advantages. The monthly sun-spot numbers show considerable irregularities which Wolf smoothed by a process similar to that employed to free the magnetic numbers from the annual inequality, the resulting numbers being used for the upper curve of the diagram.

The collected curves show striking points of interest. The epochs of the extreme points of the curves are given in the following table:—

Table of Epochs of Magnetic and Sun-spot Minima and Maxima.

Reference No.	Phase.	Magnetic epochs. Declination.	Horizontal force.	Mean magnetic.	Sun-spot epoch.	Excess above sun-spot epoch. Declination.	Horizontal force.	Mean magnetic.
						y.	y.	y.
1	Minimum ...	1844·3	1842·9	1843·60	1843·5	+0·8	−0·6	+0·10
2	Maximum ...	1848·1	1849·0	1848·55	1848·1	0·0	+0·9	+0·45
3	Minimum ...	1857·2	1855·1	1856·15	1856·0	+1·2	−0·9	+0·15
4	Maximum ...	1860·6	1860·2	1860·40	1860·1	+0·5	+0·1	+0·30
5	Minimum ...	1867·5	1867·6	1867·55	1867·2	+0·3	+0·4	+0·35
6	Maximum ...	1870·8	1870·9	1870·85	1870·6	+0·2	+0·3	+0·25
7	Minimum ...	1879·0	1878·7	1878·85	1879·0	0·0	−0·3	−0·15
8	Maximum ...	1884·0	1883·8	1883·90	1884·0	0·0	−0·2	−0·10
9	Minimum ...	1889·5	1890·0	1889·75	1890·2	−0·7	−0·2	−0·45
10	Maximum ...	1893·5	1894·0	1893·75	1894·0	−0·5	0·0	−0·25
	Mean excess (five epochs of minimum)					+0·32	−0·32	0·00
	Mean excess (five epochs of maximum)					+0·04	+0·22	+0·13
	General mean excess					+0·18	−0·05	+0·06

The intervals between the successive mean magnetic epochs and the corresponding sun-spot epochs run, it will be seen, closely together. And if instead of successive intervals we take successive periods, as from No. 1 to No. 3, No. 2 to 4, &c., of the table, we have—

Length of Magnetic Period.

1-3	2-4	3-5	4-6	5-7	6-8	7-9	8-10
y.	y.	y.	y.	y.	y.	y.	y.
12·55	11·85	11·40	10·45	11·30	13·05	10·90	9·85

Length of Sun-spot Period.

y.	y.	y.	y.	y.	y.	y.	y.
12·50	12·00	11·20	10·50	11·80	13·40	11·20	10·00

Nos. 1 to 3, 3 to 5, &c., represent intervals between successive minimum epochs, and Nos. 2 to 4, 4 to 6, &c., intervals between successive maximum epochs. These are shown graphically in the annexed figure.

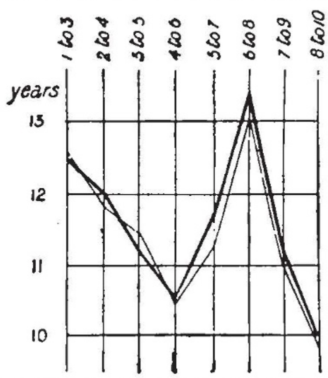

FIG. 2.—Length of sun-spot and magnetic periods compared. The thick line shows the variation in length of successive sun-spot periods, and the thin line that between successive magnetic periods. Odd numbers indicate periods from minimum to minimum, and even numbers periods from maximum to maximum.

Examining further the collected curves, it is seen that the several maximum points have at different epochs very different degrees of intensity. Arranged in order of intensity these are as follows:—

Order of Epochs.

Sun-spot curve	1870	1848	1860	1894	1884
Declination curve ...	1870	1848	1860	1894	1884
Horizontal force curve...	1870	1860	1848	1894	1884

The agreement is complete, excepting that in horizontal force the epochs 1848 and 1860 are transposed, although otherwise falling in with the order of the other curves.

The paper goes on to point out that—considering how the irregularities in the length of the sun-spot and magnetic periods, and also the order of epochs as regards elevation or depression of the maximum points of the curves, so entirely synchronise, and, further, the usually sharp rise from minimum to maximum and the more gradual fall again to minimum, a characteristic of all three curves—"there would appear to be no escape from the conclusion that such close correspondence, both in period and activity, indicates a more or less direct relation between the two phenomena, or otherwise the existence of some common cause producing both." Reference is also made to the question of the supposed lagging of the magnetic epoch, as referred to the sun-spot epoch, which the results presented do not appear much to confirm.

The paper concludes with an inquiry as to how far the practice of including in the Greenwich tabulation of magnetic elements all days (except those of extreme disturbance) may have affected the results presented, for which purpose diurnal ranges were deduced for the years 1889 to 1896 from five selected quiet days in each month—days free from magnetic disturbance—with result that the diurnal ranges so found show the same variation with sun-spots as do the diurnal ranges of the ordinary tabulation. WILLIAM ELLIS.

MONOGRAPHS OF THE UNITED STATES GEOLOGICAL SURVEY.

THE GLACIAL LAKE AGASSIZ.[1]

ONCE upon a time in North America the continental ice-sheet attained an area of about four million square miles, while its maximum thickness, in the central portion, was probably from one to two miles. It extended from the Atlantic to the Pacific, and from the northern United States to the Arctic Sea. During the closing stage of this glaciation there existed an immense lake, whose area is estimated to have been about 110,000 square miles; a lake which extended 700 miles in length, and attained a width of 250 miles. Its maximum depth was 700 feet above the present level of Lake Winnipeg.

That the idea of the former existence of this great lake is no romance of modern days, no "glacial nightmare," is indicated by the fact that so long ago as 1823 the traces of it were recognised by Keating. Not, however, until 1879 was its present name applied to it in honour of Louis Agassiz.

Placed almost in the centre of North America, and occupying what is now part of the plain of the Red River and Lake Winnipeg, together with the Lake of the Woods and other smaller sheets of water, it lay for the most part in territory now Canadian, but a fifth part occurring within the United States. In the southern region, however, its ancient shore-lines have been more exactly explored. A very large part of its area in Canada, besides a considerable tract within its limits in northern Minnesota, is covered by forest, which makes it impracticable to trace there the beach-ridges and deltas, usually but a few feet high, the low escarpments of erosion, which range from 10 to 30 feet, and the other evidences of this lake, which in the prairie region could far more readily and definitely be followed.

It was evident that the scientific study of this interesting region should not be restricted by national geographical circumstances, and it is pleasing to note that arrangements were made between Director Powell (of the U.S. Geological Survey) and Director Selwyn (of the Canadian Survey), that the work of mapping the shores of Lake Agassiz should be continued by Mr. Upham through the prairie region of south-western Manitoba. Altogether this work comprises the results of field-observations carried on during six years.

Over the greater part of the old lacustrine area there is boulder clay from 100 to 300 feet thick. A series of terminal moraines marks the stages of retreat of the ice-sheet. For a while the lake gradually increased in size northwards, finding an outlet to the south in the "glacial" River Warren, whose channel was cut to a depth of 90 feet, and whose course is now occupied by Lakes Traverse and Big Stone and by the Minnesota River. As the ice-front retreated the lake was eventually drained by the natural slope of the land to the north-east, excepting in those areas which now form the lakes of Manitoba.

The steady uplifting of the area of Lake Agassiz, resulting from the unburdening of the land by the recession of the ice-sheet, gave to its beaches a northward ascent, and caused the several shores of its southern part to become double or multiple as they are traced northward.

The author gives a full and particular account of the beaches formed at different stages in the history of the lake, and discusses various earth-movements, some of which were independent of glaciation.

His work is by no means devoid of practical value. A chapter is devoted to artesian and common wells, and to the distribution and origin of certain saline waters; and another chapter is given to the agricultural and material resources of the area.

THE FLORA OF THE AMBOY CLAYS.[1]

This work, which was very nearly finished in 1890, by the late Dr. Newberry, was placed in the hands of Mr. Hollick in 1892. His task has not been unattended with difficulty, but he has carefully indicated his necessary alterations and additions.

The Amboy Clays take their name from Perth Amboy

[1] By Warren Upham. ("Monographs of the U.S. Geological Survey," vol. xxv. Pp. xxiv + 658; 38 maps, and 35 other illustrations.)

[1] By John Strong Newberry. Edited by Arthur Hollick. ("Monographs of the U.S. Geological Survey," vol. xxvi. Pp. x + 137, with 58 plates.)