The Disturbance of Isomagnetics attending the Mino-Owari Earthquake of 1891.

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Plate XV-XXII.

Introduction.

One of the severest earthquakes in the record of this country devastated the districts about Gifu and Nagoya, on the 28th October 1891, of which a full account will shortly appear in this Journal. The Science College of the Imperial University, at the request of the writers, appointed a survey party, consisting of the writers and two advanced students of physics, Messrs. Ōta and Nakamura, for a new magnetic survey of the district affected. Frequent shocks of varying intensity occurred for a very long period after the date of the destructive one in October, and the party did not set out till some time after these shocks had sensibly ceased, namely, on the 20th December, returning on the 13th January.

The object in view in having this survey made, was to enable comparisons to be drawn between its results and those which had been previously obtained, or which might be obtained, at some future time, in order to throw light if possible, upon the effect of seismic events upon the magnetic elements of a country, and give some notion concerning the nature of the subterranean disturbances to which such events are due. For the purpose of such comparison, it is evident that a knowledge of the ordinary secular variations of the magnetic elements of the district is of paramount importance, and this unfortunately, in the present case, is to a great extent wanting, since systematic magnetic surveys of this country are of comparatively very recent date.

If we take only the declination, we may go back to the work of Inō, who made a careful comparison of the compass needle with the astronomical meridian at various places in the country during his memorable undertaking of the geodetic survey of Japan, 1800—1818. Since then we have had observations of only a fragmentary nature until the first systematic survey was carried out by the Geological Bureau (1880—1885) under the direction of Dr. E. Naumann. Two observers, Messrs Sekino and Kōdari, worked during these years over different parts of the country, the number of stations being 182 in all. The results are published in a pamphlet entitled "Die Erscheinungen des Erdmagnetismus in ihrer Abhängigkeit vom Bau der Erdrinde." Their results were, however, of a provisional character, in so far that they made but one determination of each element at every station, and that the distribution of their stations was only along certain lines. This necessitated the introduction of corrections which, as there were no better means, they took from the Tōkyō magnetographs; while as to isomagnetics much extrapolation had to be made, notwithstanding the number of stations they took. This was no fault of the observers, for they had other duties to perform at the time, and the mode of travelling was not so convenient then as it is now.

During the summer of 1887, Prof. Knott and the present writers with Mr. Imagawa made a survey, in which they tried to distribute the stations as uniformly as they could. They divided themselves into two parties, indicated as 'south' and 'north,' and as the principal work was done during the three months, July, August, and September, the errors due to the secular and seasonal variations were but small. The south party made observations of diurnal variations of declination at every station except three. This, besides giving the mean value of declination at the place, tells us the nature of the magnetic weather of the day on which other magnetic elements were determined. They made also three or four determinations of the horizontal intensity and dip, the times of observation being distributed over the day. (For details of this survey we refer to volume II of this Journal.) Had we made another series of such observations, we could have allowed for the secular variation in the results of the present survey, and should have been able to tell more definitely the kind of disturbance caused by the earthquake: but, as it is, our results will yet be of service for determining the secular variation, when, in the future, another survey shall be made, and then we may be able to draw inferences as to the effect of the earthquake by allowing for the secular variation then ascertained.

There was no particular division of work among the members of the party; generally speaking, however, the vibration and deflection experiments were carried out by the writers and either of the students; the dip was determined almost exclusively by the students; and the declination and time-observations, both for the chronometer rate and for azimuth, were undertaken by the writers.

The stations, as a simple matter of course, were those of the previous survey in 1887. Although for guidance we had verbal descriptions of the stations, and the memory of one of the party who had worked on the previous occasion, the identification of places was not always easy, as no fiducial mark of reference had been left. This was to be expected, since in the previous survey we had tried to station ourselves in places which were as far as possible from buildings and hills. Warned now by this experience, we left a wooden post with the short inscription, "磁力實測點," and the date, at each place of observation, while further we give (Pl. XV) some topographical details of the localities, as was done by Lamont, hoping thereby to save much time and labour and to give much certainty in identifying the places in future.

The four stations, Nagahama, Obama, Shioya, and Isshiki (Kamiyashiro, in previous reports), are almost identical with the former spots, *i. e.*, are within a few metres. In Nagoya, the Normal School of the province has since been built on the site of the former station, and we were obliged to have our new station a little to the east, that is, in the back part of the recreation ground. Here we made observations of dip in four places in different quarters of our tent, to see if the new building, though of wood, had any disturbing effect, and as the results agreed within reasonable limits, we assumed that it had not caused any sensible magnetic disturbance. This way of taking the dip at several points in vicinity was carried out in nearly all stations where local disturbance was feared. In Shimizu, a coal depot had been built on the site of our previous station, and the present determination was made in a place about 100 metres to the north-west along the shore. Numazu and Hamamatsu are new additional stations.

We further took some of the soil from the station and measured its magnetic permeability. This was done by measuring the magnetic moment in known field. The field was given by a solenoid of 39.1 cm. length, uniformly wound with No. 13 copper wire, to 13.7 turns per cm. in 6 layers. In order to eliminate the solenoid effect, it was placed in vertical position, and the magnetometer stood 5.2 cm. west of the middle point of the solenoid; there the direction of the field due to the ends of the solenoid is up and down, and consequently it gives no deflection so long as there is no substance in the solenoid. This position was determined experimentally by passing a strong current through the solenoid. The soil to be experimented upon was filled into a glass tube which had been tested and found to be sensibly free from magnetic matter. The inner diameter of this tube was 1.3 cm. and its length 19.55 cm. When introduced into the solenoid, its lower end was brought nearly level with the magnetometer, so that only the upper half of the solenoid was used. The magnetometer deflection was a maximum when the lower end of the glass tube was slightly below the level of the magnetometer, and in this position the reading was taken. Taking the deflection as proportional to the strength of the pole induced by the field, and applying the correction due to the upper pole, the susceptibility was easily deduced. The only soils that gave any sensible susceptibility were those of Numazu and Shimizu, two stations which are so far east of the region under consideration that they do not come into the chart of isomagnetics at the end of this paper. The results of the determinations are as follows :—

Soil from Numazu Station.			*Soil from Shimizu Station.*		
$\mathfrak{H}$	$\mathfrak{I}$	κ	$\mathfrak{H}$	$\mathfrak{I}$	κ
26.8	.0199	.00074	26.8	.0059	.00022
85.0	.0817	.00096	85.0	.0238	.00027
127.0	.1266	.00099	137.0	.0355	.00026

It is remarkable that these soils seem to be far from being saturated in these fields.

In the following description of stations we give the geological nature of the soils.*

* We are indebted to Mr. Y. Kikuchi, Assist. Prof. of Geology, for giving this information about the soils.

Numazu $\varphi = 35^\circ\ 6'$ $\lambda = 138^\circ\ 52'$

East bank of Kanōgawa, about 150 metres north of the bridge.

Soil :—Pyroxenes, olivine, plagioclase ; derived from basalt. Magnetite abundant.

Shimizu $\varphi = 35^\circ\ 0'.2$ $\lambda = 138^\circ\ 30'.3$

100 metres N of coal depot, 15 metres from the sea.

Soil :—Pyroxenes, quartz ; derived from volcanic rocks. Magnetite plentiful.

Hachimanmura $\varphi = 34^\circ\ 44'$ $\lambda = 137^\circ\ 45'$

About 200 metres N of Hachiman-Yashiro, in the farm.

Soil :—Quartz, pyroxenes, apatite, magnetite (very little), hornblende, tourmaline. Probably derived from crystalline rocks.

Nagoya $\varphi = 35^\circ\ 10'.7$, $\lambda = 136^\circ\ 55'$

In the east corner of the play ground of the normal school.

Soil :—Pyroxenes, quartz, felspar.

Nagahama $\varphi = 35^\circ\ 23'.8$, $\lambda = 136^\circ\ 16'.0$

Eastern shore of the lake, and former site of castle, edge of the mulberry farm.

Soil :—Quartz and hornstone pebbles.

Obama $\varphi = 35^\circ\ 30'.3$, $\lambda = 135^\circ\ 44'.8$

Former site of fortification, south bank of Kumagawa, 70 metres NW of Minatsuki Yashiro.

Soil :—Loam.

Shioya $\varphi = 36° 18'$, $\lambda = 136° 14'$

South shore of the Japan Sea, 150 metres N of the cremation building.

Soil :—Mostly quartz and felspar fragments.

Isshiki $\varphi = 34° 30'.4$, $\lambda = 136° 45'.3$

Middle of salt farm, former site of fort.

Soil :—Derived from slaty rocks.

Instruments and Method of Observation.

The object of the present survey being to get results closely comparable with those obtained in the previous one, we took the set of instruments that was used by the 'south' party of 1887, for the sake of eliminating instrumental peculiarities should there be any ; since the regions to be visited had then been exclusively surveyed by that party. Of the instrumental constants we give new determinations somewhat in detail.

Declination Coil.—Its length is 13.3 cm.; breadth, 13.2 cm.; height, 2.7 cm.; the space unwound in the middle 2.4 cm.: thus nearly fulfilling the condition for minimizing the error due to excentric position of the magnetometer, in which the ratios of these dimensions are 5 : 5 : 1 : 1. The coil is wound in two layers, the under layer with somewhat fine wire to 22.2 turns per cm., and the upper one with thicker wire to 13.2 turns per cm., making in all 35.4 turns. The field at the centre is $6.5 \times 35.4 \div 10 = 23$ per ampère, or 0.013 ampère will give .3, the approximate value of H in those regions, so that a Daniell element prepared in a small bottle proves sufficient to give the requisite field. Its internal resistance varies between 20 and 60 ohms., according to the strength of the solution in the Daniell cell. In order to adjust the strength of the current for use, a small resistance box consisting of 1, 2, 4, 8, 16, 32 ohms was put in the circuit. This arrangement of resistances gives the fewest number of plugs with which the resistance can be adjusted, within one ohm, from 1 up to the total sum of resistances in the box.

The method of observing the declination was the same as before described ; that is, by finding the two positions of the coil where its magnetic axis coincides with the dirction of the earth's field, in one of which the pivots are reversed after the usual fashion of collimating telescopes. The mean of the two azimuths is taken to be the position of the Y's of the theodolite in magnetic E.-W., corresponding to the instant at the middle of two observations ; and the difference as the magnetic collimation of the coil. This magnetic collimation should be constant if the instrument remains perfectly unaltered in shape. The collimation varied from $\frac{1}{2}'$ to $1'$ on different occasions. We first thought this difference to be personal, but after some number of trials, it was found that the same collimation was obtained by different observers when they worked in close succession, and that the change was gradual and in the instrument. It might be supposed that this fluctuation in the collimation is due to variation of the declination during the course of observation. But the process of observation takes only two or three minutes, in no case more than five minutes, and since the greatest change of declination is only about two minutes per hour, this change cannot be the cause. The fluctuation is due probably to temperature variation of the coil.

The position of the circle corresponding to the astronomical meridian was observed, together with the time, and was calculated, by the usual method, from simultaneous equations containing time, azimuth, and collimation.* For this sort of work the usual method of forming normal equations by differentiation is altogether superfluous, and we follow the abridged method of Cauchy. By this means we found two azimuths from two sets of observations on successive nights, when weather permitted ; on other occasions, observations were made, one in the evening, and one early next morning. The results of the two determinations usually came out within 10″; this difference is due to two sources, one the error of observation, and the other the error of graduation. The latter will be eliminated to a great extent by taking a number of observations on some circumpolar stars, and a number of readings of the azimuth circle on different parts of the graduation. For this purpose, we have published in *Sugaku-butsuri-gakkwai-kiji.*, vol. V., a somewhat extensive table of azimuths of *Polaris*, for different hour angles and latitudes, which can be used for observations of either α or λ *Ursæ Minoris* for several years to come. As these two stars differ by nearly 6 hours in right ascension, it will always be possible to take observations which differ by several minutes of arc in azimuth in course of half an hour.

Magnet.—The magnet is a solid steel bar of nearly square cross section polished on all sides. Its magnetic moment was found to have fallen a great deal, and we therefore remagnetized it a few days before starting, taking care not to reverse the previous magnetization. Placing the magnet on a glass plane, it was found to be distinctly curved. A lateral face of this magnet, which has better polish than the others, has a round spot towards the north end, and this face with the mark always served as the reflecting face in our vibration experiments. It has remained nearly plane, while the faces perpen-

* See reduction sheet at the end.

dicular to it had become slightly curved. This change of shape necessarily altered the moment of inertia of the magnet.

The dimension of the magnet was therefore redetermined. The magnet was laid on a thick plane glass plate, and placed in contact with the graduated side of the standard metre scale. This scale is of brass, constructed by Breithaupt (Hesse Cassel), and equal to one metre, at 20^0 C. The two extreme edges of the magnet were slightly convex, and were not distinct enough to serve as marks for measuring the length of the magnet. Two similar, right-angled, glass prisms were made to touch the faces of the magnet, perpendicular to its length. The edge of the prism was well defined, and was brought in the same plane with that of the metre scale. The readings of the edges of the prism were taken by means of a micrometer microscope. The magnet was placed on the glass plate on all its four faces successively, and the same series of observations repeated for each position of the magnet. The magnet was then taken off and the distance between the edges measured under the microscope. This done, the magnet was reversed and its length measured again in the same way as before.

To correct for change of length by temperature, two thermometers were placed beside the magnet, and two laid on the scale. All these thermometers were previously compared with the standard thermometer. Temperature readings were taken simultaneously with those of the micrometer. Generally, the temperature of the magnet did not differ by more than $0^\circ.1$ from that of the scale.

The following table gives the results of observations by Messrs. Ōta and Nakamura.

Observed Length of Magnet.	Position.	Temp. of Scale.	Temp. of Mag.	Length at 0°C	Observer.
cm.					
7.0053	direct.	16°.7	16°.7	7.0010	S.N.
6.9994	reversed.	16°.8	16°.9	6.9977	,,
6.9973	direct.	16°.3	16°.3	6.9956	K.O.
6.9990	reversed.	16°.6	16°.6	6.9973	,,

In the reduction of scale to 0°. C. the expansion coefficient of brass was assumed to be 0.0000189, and that of steel, 0.0000106. From the mean of these observations, the length of the magnet is 6.9979 cm. The length has thus somewhat diminished since the former determination, by which it was found to be 7.0024 cm.

The breadth of the magnet was measured at three points; *i.e.*, at the ends and at the middle. The magnet was placed perpendicular to the metre scale and between the two prisms before mentioned. The same process of measurement as used for the length, gave 0.8066 cm. at 0° C. for the mean breadth of the bar or its thickness between the face with the mark, and the one parallel to it. The breadth of the other faces is of minor importance, and has not been measured.

In weighing the magnet a Sartorius' balance was used. Care was taken not to place the magnet near any of the iron used in various parts of the balance, by not putting it on the scale pan, but suspending it from this by a slender thread, bringing it about 50 cm. below the balance case and about the same distance above the floor. The magnet was shielded from air currents by placing it in a nearly closed glass vessel. The mass of the magnet, as determined by a set of weights from Sartorius, was 35.0561 grm., and 35.0633 grm. by the set of weights formerly used. This discrepancy was cleared up by comparing these weights with those made of quartz by the same maker, belonging to the Chemical Laboratory of the College. The brass weights from Sartorius were a little heavier, and the old weights a little lighter. The following gives the results of the experiments :—

	by Sartorius weights.	by old weights.
Observed	35.0561 grm.	35.0633 grm.
Correction	+ .0038	− .0034
Mass	35.0599 grm.	35.0599 grm.

The mass of the magnet is thus 35.0599 grm.

From these measurements of length, breadth, and mass the moment of inertia of the magnet about an axis through its centre of inertia, and perpendicular to its length, is found to be 144.98 at 0°C.

The moment of inertia was calculated on the supposition that the magnet is a parallelopiped having the dimensions given above. The magnet, however, being distinctly curved, it was not satisfactory to use the moment of inertia calculated in the above manner, and it was therefore determined also experimentally.

This was done in the usual way by comparing the times of vibration, with and without an additional inertia. In order to eliminate the diurnal variation of H, the vibrations were repeated several times in which the inertia rod was alternately on and off. The inertia rod was a solid cylinder of brass belonging to a Kew magnetometer (64) (length = 9.545 cm., diameter = 0.997 cm., mass = 63.071 grm.) From the comparison of the times of vibration in these two cases, the moment of inertia was found to be 144.995. The following table gives the results of observations by Mr. Ōta :—

Observed time of vibration.

Magnet alone.	Temp.	Magnet with inertia red.	Temp.
$2^s.7276$	$19^0.1$		
		$5^s.6783$	$17^0.1$
2.7244	$16^0.2$		
		5.6736	$15^0.0$
2.7231	$14^0.6$		
		5.6743	$15^0.0$
2.7238	$14^0.7$		
Deflection for complete rotation of torsion head.	$11'.1$	Deflection for complete rotation of torsion head.	$13'.8$

The temperature coefficient for the moment of the magnet was taken from calculations made on the observations at Isshiki.

Temperature Coefficient of Magnetic Moment:—In the former survey, no correction for the difference of temperature in vibration and deflection experiments was applied in the reduction of the observations of horizontal intensity. This gives the moment of the magnet at mean temperature; but the value of the horizontal intensity is affected inasmuch as the magnetic moment was different in the two experiments; it will have been less if the temperature was higher in the vibration than in the deflection experiment, and *vice versâ*.

The determination of the temperature coefficient of a magnet is a matter of some difficulty. It is desirable to determine the effect of temperature on the magnetic moment by placing the magnet in the same state as in the determination of horizontal intensity. By taking the number of observations of horizontal intensity at different hours of the day, so that there is sufficient difference of temperature during the experiments, we can obtain data for the calculation of the temperature coefficient. With this object in view, many observations of the horizontal intensity were made at Nagoya.

The magnet, however, showed a sudden decrease of moment at Nagahama. It is likely that the temperature coefficient after this fall of moment was different from that at Nagoya. By using the moments found at Isshiki, the temperature coefficient was recalculated. For reducing the results of the former survey, the temperature correction was calculated from determinations of magnetic moment made at Miyazaki.

The following empirical formula was used in the calculation,

$$M=M_0+m+a\ (t-t_0)+b\ (t-t_0)^2$$

where M_0 is the mean of the moments used, m a small correction to be applied to M_0, t_0 the mean temperature, and a, b the coefficients to be determined. The above formula was then transformed, for convenience of calculation, to

$$M_t=M_\tau\ \{1+\alpha(t-\tau)+\beta(t-\tau)^2\}$$

where τ is any convenient temperature. The following gives the data and results of calculation from observations made at Nagoya, Isshiki, and Miyazaki :—

Nagoya.

Magnetic Moment.	Temperature.	
670.86	16°.23	
671.03	16 .12	$M_0=673.49$
671.93	14 .84	$m=-\ 0.02$
673.32	11 .13	$t_0=\ 11^\circ.48$
675.06	8 .00	$a=-\ 0.546$
675.90	7 .53	$b=+\ 0.0046$
676.44	6 .49	

whence $M=674.31\{1-.00083(t-10^\circ)+.0000068(t-10^\circ)^2\}$

Isshiki.

Magnetic Moment.	Temperature.		
656.90	11°.28		
657.55	9 .03		
657.95	8 .38	$M_0=$	658.19
657.81	8 .14	$m=-$	0.05
660.79	2 .07	$t_0=$	7°.83
658.17	8 .55	$a=-$	0.418
656.61	11 .25	$b=$	0.0057
659.77	3 .93		

whence $M=657.26\{1-.00060(t-10^\circ)+.0000087(t-10^\circ)^2\}$

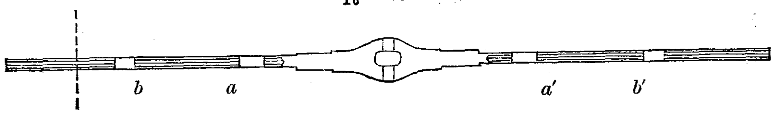
Miyazaki.

Magnetic Moment.	Temperature.	
436.945	34.6	
437.01	34.8	$M_0=437.45$
437.07	34.0	$m=-0.04$
437.19	33.35	$t_0=32^\circ.33$
437.58	31.6	$a=-0.221$
437.95	29.6	$b=0.0076$
438.44	28.35	

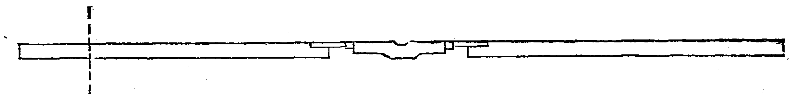
whence $M=437.96\{1-.000586(t-30^\circ)+.0000174(t-30^\circ)^2\}$

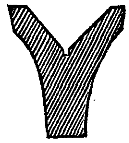
Deflection Rod :—The rod is of brass and about 1 metre long. The accompanying figures show the rod in horizontal and vertical projections, as well as in cross section. **V** grooves are cut all along the slender parts $a\ b$, $a'\ b'$ of the rod. When the magnet is laid on **V**, the diagonal of the square cross section of the magnet is on a level with the upper face of the rod. To facilitate the change of position of

$\frac{1}{10}$ natural size.



$\frac{1}{10}$ natural size.





Natural Size.

the deflecting magnet and to restore it always to the same place, four stops *a*, *b*, *a′*, *b′* are rigidly fixed to the rod. These stops are triangular prisms of brass fitting into the **V**. Each has a slightly oblique section. It is so fixed to the rod that the magnet comes in contact with the acute edge of the prism along the diagonal of the square section. Before placing the magnet on the **V**, the groove was always carefully swept with a camel's hair brush, so as to make sure of contact, both along the groove, and against the stop. The magnet was placed in such a position that the lateral face with the spot before spoken of was always turned from the observer. The magnet was slid by the end of the brush along the groove. In transferring it from one to the other side of the rod, or in reversing it, care was taken to guard against change of temperature from handling, by wrapping it in a piece of folded crape.

The temperature of the rod was read by means of two thermometers (Salleron No. 1386 and No. 15476), each graduated to $\frac{1}{5}$ of a degree. They were loosely attached, one to each branch of the rod. One of the thermometers was placed in front of the observer, and the other at the back. These thermometers were compared with the standard and corrected.

During the former survey, the magnet remained straight and came into good contact with the stops and therefore the distances, r_1 and r_2, of the magnet from the magnetometer magnet were known from the measurements of the distances a a', b b', and the length of the magnet. But as the magnet had become decidedly curved, it would no longer come into good contact with the stops. Generally, only one extremity of the diagonal of the square cross-section was in contact, while there was a slight gap at the other end. This change of contact necessitated the redetermination of the distances of the centre of the magnet in positions a, b, a', b'. The actual distances of the centre of the magnet from the magnetometer magnet can only be determined by placing the magnet in the groove in the same way as in the actual deflection experiments.

The deflection rod was placed on a plane plank, and the lower side of the metre scale was brought in contact with the upper face of the rod. To guard against any change of position of the metre scale and the rod, the latter was gently clamped to the plank at its middle, and any relative motion which might take place between the two during measurement was noted by a microscope of high magnifying power. No relative motion of the scale and rod was observed during the operation. The magnet being placed in the usual way in the groove, the edge of the magnet adjacent to the stop was sighted, and the, readings of the scale and micrometer noted in the four positions a, b. a', b'. The magnet was then reversed, and the process repeated. The rod being next reversed, the readings of the other edge of the magnet were noted in the same position as before. For each reading of the micrometer, four thermometers were read, two being placed on the scale and the others close to the rod. The mean of the observed lengths are.—

$$a\,a'=39.0759 \text{ cm. at } 0^{0} \text{ c.}$$
$$b\,b'=67.0196 \text{ cm. ,, ,, ,,}$$

The distance between the edges of the magnet was next measured, both in the direct and in the reversed positions. The mean length of the magnet from one edge to the other was found equal to 6.9905 cm. at 0^{0} C. Thus we have for the distances of the centre of the magnet from the magnetometer magnet.—

$$r_1=30.0196 \text{ cm. at } 0^{0} \text{ C.}$$
$$r_2=23.0332 \text{ ,, ,, ,, ,,}$$

It is to be noticed that the distances of the magnet from the magnetometer magnet will be slightly different unless the latter be accurately centred. Since the centering of the magnetometer magnet can be easily done with sufficient accuracy, and since the correction te be made from this cause would be only of the order of the square of this error, it was quite negligible in our observations.

The distances of the magnet for two positions, a and b, had to be corrected for the expansion of the rod as well as for that of the magnet. If the expansion coefficient of brass be α, and that of steel be β, it can be easily shown that in place of the factor $(1+3\,\alpha\,t)$ (see specimen sheet in the former report), used in the calculation of M/H in the former survey, we must use.—

$$1+3\,\alpha\left(1+\frac{\alpha-\beta}{\alpha}\,\frac{l}{r_1+r_2}\right)t$$

where l denote the half length of the magnets.

Taking $\alpha=0.0000189$, $\beta=0.0000106$, $l=7/2$, $r_1=30$, $r_2=23$, the value of the coefficient becomes—

$$1+3.08\,\alpha t;$$

or its effect is to increase the temperature coefficient by about 3 per cent.

Correction for the induced Magnetism :—The magnetic moment arising from the magnetization induced in the vibration magnet by a given magnetic field, comparable with that of the earth, was determined by the magnetometric method. The magnet was placed on the deflection bar, as in the actual deflection experiment, and was subjected to various weak fields obtained by means of a solenoid enclosing the magnet and the bar together. The deflection due to the permanent magnetism of the magnet was compensated by means of another bar magnet placed on the other side of the magnetometer on the deflection bar. A solenoid, 23 cm. in length and 2.6 cm. in diameter, was wound in four layers with fine insulated copper wire, the total number of turns being 71 per cm. The effect of the solenoid alone was calculated by observing the deflections when the known current was passed through the solenoid, the magnet being taken away. This deducted from the deflection when the magnet was put in, gave the deflection proportional to the moment induced by the field. For observing the deflection, a scale cut in mm., was placed at a distance of 4.2 metres from the magnetometer. By means of a telescope, the deflection could be read to the tenth of a scale division. At each observation of deflection, the magnetometer zero was noticed, to guard against any changes of declination. The following are the results obtained by Messrs. Ota and Nakamura :—

Field.	Increment of moment.	μ (Increase of M per unit field)
.157 (direct)	.101	6.43
.306 ,,	.201	6.56
.157 (reverse)	.102	6.50
.306 ,,	.199	6.51
	Mean.	6.50

This result is greater than the value used in reducing the observations of 1887. The induction coefficient then used was 3.6, and was deduced from the observations made in 1883 on the magnet from which the present magnet was prepared by cutting off its end.

We tested the result by the ballistic galvanometer method. For this purpose a coil, into which the magnet fitted almost exactly, was wound, and its ends were led to a low resistance ballistic galvanometer which was 10 metres distant from the coil. The coil lay on a horizontal plane with its axis parallel to the magnetic meridian, and it was adjusted to this position by means of a wooden block. When the coil was quickly turned round through half a revolution in the horizontal plane the ballistic galvanometer gave deflections proportional to the number of lines of force through the solenoid due to the horizontal component of the earth's field. Now the bar magnet was put into the solenoid, and the experiment repeated; the magnet was introduced again with its axis reversed, so as to eliminate its direct effect on the galvanometer. The following is the result of this experiment :—

Mean of 10 readings of galvanometer throw without magnet	9.1
" " " " " " with magnet	125.7
Volume of magnet	4.5 c. cm.

The ratio of the volume included by the solenoid to that of the magnet is 1.44; whence $\mu = \frac{116.6}{9.1} \times \frac{4.5}{4\pi} \times 1.44 = 6.62$, which is greater than the value obtained by the other method. The difference is such as might be expected from the difference in the methods, as the first partly depends upon the distribution of induced magnetism in the magnet, and the second on the integral effect of induction on the substance. In applying the correction due to induced magnetism in the reduction of our observations, we have taken the value obtained by the first experiment, as it refers more directly to the point in question.

As we suspected that the change in the value of μ might be due to the change in the tempering of the magnet, caused probably by the annual variations of temperature during the years intervening, we made experiments on a similar magnet newly made, before applying this correction to the previous results. The bar was tempered as hard as we could make it, and the experiment was performed both in the unmagnetized and in the magnetized state. In both cases the value came out in slight excess of the values of the old magnet, contrary to the above supposition ; we therefore apply the correction to our previous results. The values of H for 1887 recalculated by applying all the necessary corrections are found in the appendix.

Dip.—This was also the instrument that was used in 1887, *i.e.*, No. 88 Dover. Needle No. 2 was always used.

Results of the Survey.

The individual determinations of the magnetic elements are given in full in the table appended to this paper. We here compare the mean values with those of the previous survey.

DIP

Station.	1887	1891-2	Difference.
Numazu	——	48^0 29′.0	—
Hamamatsu	——	48^0 20′.2	—
Nagoya	48^0 58′.2	48^0 53′.8	−4′.4
Nagahama	49^0 17′.6	49^0 13′.6	−4′.0
Obama	49^0 30′.4	49^0 23′.5	−6′.9
Shioya	50^0 30′.8	50^0 25′.1	−5′.7
Isshiki	48^0 16′.8	48^0 16′.7	−0′.1
Shimizu	48^0 41′.3	48^0 37′.1	−4′.2

DECLINATION

Station.	1887	1891-2	Difference.
Numazu	——	4° 19′.45	—
Hamamatsu	——	4° 18′.92	—
Nagoya	4° 31′.9	4° 38′.56	+6′.66
Nagahama	4° 45′.1	4° 42′.81	−2′.29
Obama	4° 54′.1	4° 49′.30	−4′.80
Shioya	4° 59′.2	4° 56′.15	−3′.05
Isshiki	4° 21′.8	4° 23′.91	+2′.11
Shimizu	4° 2′.1	4° 4′.42	+2′.31

HORIZONTAL INTENSITY

Numazu	——	.30102	——
Hamamatsu	——	.30141	——
Nagoya	.29903	.30125	+.00222
Nagahama	.30039	.30086	+.00047
Obama	.30020	.30195	+.00175
Shioya	.29551	.29668	+.00117
Isshiki	.30210	.30288	+.00078
Shimizu	.30016	.30070	+.00054

TOTAL INTENSITY

Numazu	——	.45414	——
Hamamatsu	——	.45342	——
Nagoya	.45553	.45823	+.00270
Nagahama	.46058	.46069	+.00011
Obama	.46230	.46391	+.00161
Shioya	.46471	.46562	+.00091
Isshiki	.45395	.45511	+.00116
Shimizu	.45467	.45487	+.00020

The mean values of these elements are the arithmetical mean of all the observed values, except those for the declination, which are obtained in a different way. The curves given in Pl. XVI and XVII were traced upon tracing cloth, cut out and weighed. From the ratio of their weights to that of a rectangular piece of the same cloth covering 24 hours the mean value was easily deduced. This procedure we found more practical than that with Amsler's planimeter.

Through the kindness of Mr. K. Nakamura of the Central Meteorological Observatory, the photographic records of the magnetic elements at Tōkyō during the present survey were placed at our disposal. The inspection of these records showed us that the magnetic weather during the survey was generally fair, except on three days on which we were taking observations at Obama, Shioya, and Isshiki. The disturbances do not appear to be very serious, and as our curves of declination obtained in those places are not far from being regular, we take the mean value without applying any correction.

During the course of the survey, we felt two earthquakes, one at Nagoya and the other at Shioya. The former was not very severe but was accompanied by the usual rumbling, the latter though not accompanied by sound was a much stronger one. Both of them happened while we were observing declination, and we took observations of declination immediately the shock was over. Pl. XVI shows that the declination suffered a distinct fall at Nagoya but resumed its regular course after an interval of some minutes. In Shioya the fall was not so marked as in the case of Nagoya, especially as the shock happened in that part of the day in which the declination was rapidly falling. Whether this is due to change in the direction of the earth's field, or to distortion of azimuth on the part of the instrument, or in the ground on which it stood, we can not tell. In the case of the

Nagoya observations certainly, it is more than can be ascribed to the displacement of the instrument, as the azimuth determined on the two successive nights, one before and the other after the event, agreed within 6″: on both nights the transits of 7 stars were taken, the reduction sheet of which we here append.

Nagoya: December 24.3 Chronometer mean solar, No. 1594 Negus.

Observer, A. Tanakadate

STAR.	δ	α	Z. D.	Clamp.	T(obs.)	Rate.	Diur. Aber.	Bb.	α-T(corr)	A.	C.
		h m s			h m s	s	s	s	h m s		
α Pers.	49°29′	3 16 36.76	14°18′ N	W	10 14 21.04	−3.79	−0.03	+1.15	6 57 41.61	−0.378	+1.539
ϵ Eridani	−9°50′	3 27 50.73	44°59′ S	W	10 25 31.40	−1.98	−0.02	+0.55	39.22	+0.718	+1.015
ν Pers.	42°14′	3 37 51.50	7° 4′ N	W	10 35 29.32	−0.34	−0.02	+1.03	38.49	−0.165	+1.351
ζ Pers.	31°34′	3 47 20.65	3°36′ S	E	10 44 58.70	+1.18	−0.02	−0.05	39.16	+0.073	−1.173
ξ Pers.	35°29′	3 51 57.53	0°19′ N	E	10 49 34.80	+1.72	−0.02	−0.05	38.98	−0.007	−1.228
ν Tauri	5°41′	3 57 24.86	29°29′ S	E	10 55 2.04	+2.82	−0.02	−0.04	39.94	+0.495	−1.005
Gr. (2320) *s.p.*	111°55′	4 5 58.63	76°42′ S	E	11 3 32.40	+4.21	+0.04	+0.02	38.04	+2.310	+2.374

Observations reduced to $3^{h}\ 40^{m}$. local sidereal time.

Whence

$$-\ 1.379\,c + 7.110\,a = +\ 5^{s}.69$$

$$+\ 12.969\,c - 1.186\,a = -\ 3^{s}.93.$$

$$a = +\ 0^{s}.76 = +\ 11.''3\,;$$

$$c = -\ 0^{s}.23$$

Azimuth reading 61° 7′ 50″

\+ 11″

Meridian reading 61° 7′ 61″

Nagoya: December 25.2 Chronometer mean solar, No. 1594 Negus.

Observer, A. Tanakadate

Star.	δ	α	Z. D.	Clamp.	T(obs.)	Rate.	Diur. Aber.	Bb.	α-T(corrd.)	A	C
		h m s			h m s	s	s	s	h m s		
α Peg.	14°38′	22 59 21.46	20°33′ s	W	5 53 53.64	−4.15	−0.02	−0.27	6 54 27.74	+0.363	+1.033
τ Peg.	23° 9′	23 15 16.11	12° 1′ s	W	6 9 46.04	−1.57	−0.02	−0.30	28.04	+0.224	+1.080
4 Cassiop.	61°42′	23 20 0.42	26°31′ N	W	6 14 29.88	−0.81	−0.04	−0.53	28.08	−0.941	+2.109
λ Draco. *s.p.* ..	69°55	23 25 0.09	74°52′ N	E	6 19 26.69	0.00	+0.05	+0.42	27.07	+2.811	+2.912
ι Andro.........	42°40′	23 32 48.91	7°30′ N	E	6 27 15.96	+1.26	−0.02	−0.73	27.56	−0.177	−1.360
ω² Aquil.........	-15° 9′	23 37 6.26	50°18′ s	E	6 31 32.72	+1.96	−0.02	−0.36	28.04	+0.797	−1.036
41 H. Ceph......	67°13′	23 42 42.69	32° 3′ N	E	6 37 11.06	+2.87	−0.04	−1.18	30.02	−1.370	−2.581

Observations reduced to $23^{h}\,25^{m}.$ local sidereal time

Whence

$$+\ 4.741\ c + 6.459\ a = 2\overset{s}{.}81$$

$$+\ 9.199\ c + 0.396\ a = 1\overset{s}{.}78$$

$$a = +\ 0\overset{s}{.}30 = 4.''5\ ;$$

$$c = +\ 0\overset{s}{.}18$$

Azimuth reading 61° 7′ 50″
+ 5″
Meridian reading 61° 7′ 55″

A glance at the list of mean values will show that there is a change in all the elements, which are of different magnitude in different stations. In order to make this change more intelligible we have drawn isomagnetic charts of the region, both from the previous and the present results. Although we by no means pretend that the number of stations was sufficient to exhibit the actual magnetic condition of the district with detail, yet we believe that these lines are not far from representing the general course of isomagnetics about those regions. And this was all that we could do during the three weeks of winter vacation which we had to spare.

From the mean values at the stations, the intermediate values were interpolated graphically, by assuming the proportionality of the space variation of the elements between two stations, taking care to interpolate *across* the isomagnetics as much as possible. For the horizontal intensity and declination, as well as for the total intensity of the previous survey, the values obtained at Nagoya were so much out of the way that we at once perceived a local disturbance. We therefore excluded Nagoya in the first interpolation, as it would be wrong to assume proportionality across the space between which there is a maximum or minimum. When the isomagnetics are drawn with this exclusion, the course of the curves throws much light upon the nature of the local disturbance, which we indicate, according to our conjecture, by dotted lines.

We notice from these charts, that the general nature of the change is to make the lines more uniform than they were before. This is remarkably shown by the observations made in Nagoya where the local disturbance is very much reduced. Of all the systems of isomagnetics, the change for the equal horizontal intensity is the most striking. By the old survey these lines were considerably deflected from their general course, forming a kind of *ridge* along the Mino–Owari plane up to the north coast of Japan. By the new survey they are made more uniform, still converging towards the Wakasa Sea, beyond which the above named ridge might be carried.

Another remarkable point is that there was a minimum of total intensity about Nagoya, which now, by the new survey, causes only a small bend in the line of equal total intensity that passes very near the place. With regard to the lines of equal dip the change is least marked. The bending of these lines towards the south are principally caused by the value of dip at Isshiki. In passing, we may remark that Isshiki lies very near the now well-known tectonic ridge along which the geological aspect of the country is suddenly changed. Another observation at a station somewhere between Tsu and Yokkaichi might tell whether this bend exists in the region generally, or whether it is of a more local character and peculiar to the southern coast.

As was stated in the introduction, we can not ascribe these changes solely to the effect of the earthquake, without thorough knowledge of the secular variation. But the very appearance of these charts is enough to show that they are anything but usual. The most important and interesting question that naturally arises will be—Are these changes of the magnetic state caused suddenly by the earthquake, or have they been taking place wholly or partly before it ? The only results that we can refer to for information about the secular variation, are those of Messrs. Sekino and Kōdari. Mr. Sekino made 13 observations in various places in the close neighbourhood of Nagoya. About Nagahama and Obama there are no observations until we come to the region near Fukui, where Mr. Kōdari made 7 observations. The values of H as obtained by these observers are such as to change the course of the lines of equal horizontal intensity in those regions both in the chart for 1887 and in that given by Dr. Naumann in his paper : thus in the district near Nagoya H is .29, while in places near Fukui, which are 2 or 3 degrees north, the values of H are nearly .300, sometimes .304. It is difficult to conceive how Dr. Naumann obtained his lines of equal horizontal intensity as given in his chart, unless he excluded either of these sets of observations.

If we take Mr. Sekino's results in the neighbourhood of Nagoya as consistent among themselves, the course of the lines of equal horizontal intensity is very different from either of the two systems we obtained, as shown by dots in Pl. XIX. Considering that the course of these curves will be independent of the instrumental constants, we feel sure of the fact that these lines have been undergoing considerable variation during recent years about the Nagoya district.

The fact that the horizontal intensity has suffered the most disturbance, seems to show that the seat of that disturbance, if it exist at all, does not lie at great depth; and this is further confirmed by the smallness of the disturbances of all the other elements. Examining the chart that was provisionally prepared for the report of the previous survey, which is more detailed than the one published, we find the same kind of disturbance near Hamada—namely convergence of the lines of equal horizontal intensity towards the place; and we now recollect that it was here that the earthquake, which was the severest one preceding the present, was felt in 1872. Whether this disturbance is due to the change of magnetic condition of the earth's crust in the vicinity caused by strain, or to the change in conductivity for earth currents, or, again, is the result of the dislocation of the magnetic crust, is more than we can decide from the scanty data which we now possess. These points will undoubtedly afford most interesting subjects of research in the future.

Declination.

Station.	Declination.	Date and Hour. (L. M. T.)
Numazu	4° 21′ 26″	December 21 2h 34m.8 p.m.
	4° 21′ 3″	„ „ 3 35.9 „
	4° 20′ 41″	„ „ 3 52.1 „
	4° 21′ 3″	„ „ 6 0.2 „
	4° 18′ 43″	„ „ 7 41.5 „
	4° 19′ 41″	„ „ 9 18.0 „
	4° 19′ 31″	„ 22 7 2.0 a.m.
	4° 18′ 46″	„ „ 9 12.6 „
Hachimanmura ... ... near Hamamatsu	4° 19′ 52″	„ 22 4 53.2 p.m.
	4° 15′ 54″	„ „ 8 51.3 „
	4° 17′ 39″	„ „ 10 13.0 „
	4° 18′ 37″	„ 23 7 55.0 a.m.
	4° 18′ 9″	„ „ 10 34.1 „
	4° 18′ 19″	„ „ 10 40.0 „
	4° 19′ 29″	„ „ 11 35.9 „
	4° 19′ 30″	„ „ 0 3.6 p.m.
	4° 20′ 44″	„ „ 1 18.1 „
	4° 20′ 51″	„ „ 2 36.4 „
	4° 18′ 49″	„ „ 4 14.2 „
	4° 17′ 54″	„ „ 6 55.5 „
	4° 17′ 34″	„ „ 7 10.9 „
	4° 17′ 44″	„ „ 7 37.7 „
	4° 18′ 22″	„ „ 9 1.4 „
	4° 18′ 21″	„ „ 9 56.8 „
	4° 19′ 4″	„ „ 11 15.9 „
	4° 18′ 57″	„ 24 0 27.2 a.m.
	4° 18′ 22″	„ „ 6 36.8 „
	4° 18′ 26″	„ „ 7 34.1 „
	4° 16′ 58″	„ „ 9 11.9 „
	4° 16′ 57″	„ „ 10 2.3 „
Nagoya	4° 39′ 20″	„ 24 7 44.3 p.m.

Station.	Declination.	Date and Hour. (L. M. T.)		h	m	
Nagoya	4° 38′ 50″	December	25	0	4.8	a.m.
	4° 37′ 42″	,,	,,	7	28.6	,,
	4° 36′ 35″	,,	,,	8	28.3	,,
	4° 36′ 47″	,,	,,	9	49.7	,,
	4° 37′ 23″	,,	,,	10	58.6	,,
	4° 39′ 48″	,,	,,	0	2.9	p.m.
	4° 40′ 44″	,,	,,	0	54.1	,,
	4° 40′ 18″	,,	,,	1	9.7	* ,,
	4° 40′ 37″	,,	,,	1	47.7	,,
	4° 40′ 18″	,,	,,	2	35.7	,,
	4° 40′ 2″	,,	,,	2	49.1	,,
	4° 38′ 59″	,,	,,	3	45.9	,,
	4° 37′ 58″	,,	,,	4	31.0	,,
	4° 38′ 4″	,,	,,	5	52.5	,,
	4° 39′ 20″	,,	,,	7	9.9	,,
	4° 38′ 53″	,,	,,	8	34.3	,,
	4° 38′ 52″	,,	,,	9	10.8	,,
	4° 38′ 25″	,,	,,	10	37.3	,,
	4° 36′ 42″	,,	26	7	43.6	a.m.
	4° 34′ 48″	,,	,,	9	4.5	,,
	4° 34′ 50″	,,	,,	9	59.7	,,
	4° 35′ 25″	,,	,,	10	6.7	,,
Nagahama	4° 33′ 48″	,,	27	11	45.6	a.m.
	4° 43′ 53″	,,	,,	0	43.3	p.m.
	4° 43′ 35″	,,	,,	1	59.7	,,
	4° 42′ 50″	,,	,,	3	16.8	,,
	4° 43′ 23″	,,	,,	3	48.3	,,
	4° 42′ 23″	,,	,,	4	51.3	,,
	4° 42′ 5″	,,	,,	6	35.4	,,
	4° 41′ 33″	,,	,,	7	35.3	,,

* Earthquake at 0ʰ 59.1ᵐ p. m.

Station.	Declination.	Date and Hour. (L. M. T.)
Nagahama	4° 40′ 50″	December 28 8h 27m.8 a.m.
	4° 40′ 24″	„ „ 9 35.8 „
	4° 42′ 10″	„ „ 10 52.0 „
	4° 43′ 23″	„ „ 11 49.5 „
	4° 44′ 15″	„ „ 0 15.5 p.m.
	4° 45′ 8″	„ „ 1 9.4 „
	4° 44′ 15″	„ „ 2 6.3 „
	4° 44′ 0″	„ „ 4 15.3 „
	4° 43′ 3″	„ „ 5 14.5 „
	4° 42′ 50″	„ „ 7 3.4 „
	4° 42′ 35″	„ „ 8 31.3 „
	4° 42′ 48″	„ „ 8 47.9 „
	4° 43′ 5″	„ „ 8 52.2 „
	4° 42′ 50″	„ „ 10 39.4 „
	4° 42′ 23″	„ 29 1 1.6 a.m.
	4° 42′ 38″	„ „ 5 22.6 „
	4° 40′ 58″	„ „ 8 14.5 „
Obama	4° 49′ 38″	„ 30 0 54.4 a.m.
	4° 47′ 54″	„ „ 9 24.7 „
	4° 48′ 39″	„ „ 10 4.0 „
	4° 50′ 42″	„ „ 11 43.0 „
	4° 50′ 5″	„ „ 0 20.9 p.m.
	4° 50′ 5″	„ „ 0 33.4 „
	4° 49′ 15″	„ „ 1 57.9 „
	4° 48′ 43″	„ „ 2 21.1 „
	4° 48′ 43″	„ „ 4 20.6 „
	4° 49′ 13″	„ „ 5 26.2 „
	4° 48′ 53″	„ „ 10 43.4 „
	4° 50′ 43″	„ 31 5 22.3 a.m.
	4° 51′ 23″	„ „ 8 36.1 „
Shioya	4° 56′ 2″	(1892) January 3 4 24.3 p.m.

Station.	Declination.	Date and Hour. (L. M. T.)			
				h m	
Shioya	4° 55′ 49″	January	3	4 31.7	p.m.
	4° 56′ 0″	,,	,,	8 4.3	,,
	4° 56′ 28″	,,	,,	9 36.6	,,
	4° 54′ 49″	,,	4	2 46.8	a.m.
	4° 55′ 39″	,,	,,	6 20.9	,,
	4° 54′ 41″	,,	,,	8 16.0	,,
	4° 54′ 52″	,,	,,	9 32.3	,,
	4° 56′ 6″	,,	,,	10 32.6	,,
	4° 57′ 34″	,,	,,	11 30.2	,,
	4° 57′ 44″	,,	,,	11 34.1	,,
	4° 58′ 57″	,,	,,	0 25.0	p.m.
	4° 59′ 34″	,,	,,	1 30.7	,,
	4° 59′ 27″	,,	,,	2 17.2	,,
	4° 58′ 27″	,,	,,	3 11.7	,,
	4° 57′ 4″	,,	,,	3 56.9	,,
	4° 56′ 22″	,,	,,	5 28.8	,,
	4° 56′ 29″	,,	,,	6 12.9	,,
	4° 56′ 33″	,,	,,	7 12.7	,,
	4° 55′ 24″	,,	,,	9 18.9	,,
	4° 54′ 47″	,,	5	1 59.5	a.m.
	4° 55′ 9″	,,	,,	4 46.6	,,
	4° 54′ 32″	,,	,,	7 19.1	,,
	4° 56′ 27″	,,	,,	8 29.9	,,
	4° 57′ 29″	,,	,,	9 24.3	,,
Isshiki	4° 22′ 18″	,,	8	10 24.9	a.m.
	4° 23′ 1″	,,	,,	11 5.9	,,
	4° 24′ 32″	,,	,,	0 2.8	p.m.
	4° 25′ 49″	,,	,,	0 56.7	,,
	4° 25′ 44″	,,	,,	1 59.4	,,
	4° 24′ 58″	,,	,,	2 44.7	,,
	4° 24′ 52″	,,	,,	3 26.4	,,

Station.	Declination.	Date and Hour. (L. M. T.)
Isshiki	4° 24′ 38″	January 8 4^h 8.0^m p.m.
	4° 23′ 58″	„ „ 4 51.4 „
	4° 23′ 28″	„ „ 6 53.8 „
	4° 24′ 7″	„ „ 7 46.1 „
	4° 23′ 47″	„ „ 9 9.0 „
	4° 23′ 56″	„ „ 10 54.6 „
	4° 24′ 10″	„ 9 6 39.8 a.m.
	4° 23′ 13″	„ „ 7 38.6 „
	4° 21′ 38″	„ „ 8 38.6 „
	4° 21′ 38″	„ „ 9 31.1 „
	4° 21′ 30″	„ „ 10 7.7 „
	4° 24′ 20″	„ „ 0 4.4 p.m.
	4° 25′ 55″	„ „ 1 49.8 „
	4° 26′ 37″	„ „ 2 44.7 „
	4° 26′ 7″	„ „ 3 34.7 „
	4° 25′ 15″	„ „ 4 23.2 „
	4° 24′ 30″	„ „ 5 0.3 „
	4° 24′ 33″	„ „ 6 31.7 „
	4° 23′ 25″	„ „ 7 25.8 „
Shimizu	4° 6′ 46″	„ 11 1 14.5 p.m.
	4° 6′ 46″	„ „ 1 40.1 „
	4° 6′ 58″	„ „ 2 33.5 „
	4° 5′ 34″	„ „ 3 37.3 „
	4° 4′ 56″	„ „ 4 23.6 „
	4° 4′ 31″	„ „ 6 21.6 „
	4° 4′ 14″	„ „ 7 35.5 „
	4° 3′ 42″	„ „ 9 22.5 „
	4° 4′ 32″	„ „ 10 33.5 „
	4° 4′ 13″	„ „ 11 27. „
	4° 3′ 19″	„ 12 8 1.7 a.m.
	4° 2′ 49″	„ „ 8 53.1 „

Station.	Declination.	Date and Hour. (L. M. T.)
Shimizu	4° 2′ 32″	January 12... 9ʰ 58.0ᵐ a.m.
	4° 2′ 44″	„ „ 10 46.0 „
	4° 5′ 14″	„ „ 11 48.8 „
	4° 7′ 18″	„ „ 0 53.6 p.m.
	4° 7′ 12″	„ „ 1 19.3 „
	4° 7′ 23″	„ „ 1 47.4 „
	4° 7′ 19″	„ „ 2 41.0 „
	4° 7′ 12″	„ „ 3 15.2 „
	4° 7′ 14″	„ „ 3 56.4 „
	4° 6′ 37″	„ „ 4 24.4 „
	4° 5′ 57″	„ „ 6 16.1 „
	4° 5′ 13″	„ „ 7 11.5 „
	4° 4′ 59″	„ „ 7 59.0 „

Dip.

Station.	Dip.	Date and Hour. (L. M. T.)				
				h	m	
Numazu...	48° 29′.4	December	21	1	41.8	p.m.
	48° 26′.6	„	„	3	7.3	„
	48° 30′.6	„	„	10	2.8	„
	48° 29′.3	„	22	8	34.4	a.m.
Hachiman-mura ... ... near Hamamatsu.	48° 20′.6	„	22	4	24.9	p.m.
	48° 21′.1	„	„	10	39.1	„
	48° 20′.0	„	23	9	14.4	a.m.
	48° 19′.5	„	„	2	3.2	p.m.
	48° 19′.0	„	„	9	36.8	„
	48° 20′.7	„	24	9	43.9	a.m.
Nagoya	49° 1′.4	„	24	7	55.4	p.m.
	48° 58′.8	„	25	8	9.8	a.m.
	48° 50′.5	„	„	3	19.8	p.m.
	48° 54′.5	„	„	5	16.3	„
	48° 49′.5	„	„	7	37.6	„
	48° 52′.3	„	„	8	13.9	„
	48° 51′.3	„	„	8	52.1	„
	48° 51′.9	„	26	9	33.9	a.m.
Nagahama	49° 13′.9	„	27	0	18.7	p.m.
	49° 13′.3	„	„	4	22.1	„
	49° 16′.9	„	28	10	30.6	a.m.
	49° 16′.9	„	„	11	15.2	„
	49° 11′.7	„	„	2	51.3	p.m.
	49° 12′.5	„	„	3	51.1	„
	49° 10′.2	„	„	about midnight.		
Obama	49° 23′.4	„	29	11	5.0	p.m.
	49° 26′.3	„	30	9	48.9	a.m.
	49° 22′.7	„	„	0	3.9	p.m.
	49° 22′.8	„	„	1	13.1	„
	49° 23′.2	„	„	2	3.6	„
	49° 22′.6	„	„	4	1.3	„

Station.	Dip.	Date and Hour. (L. M. T.)			
Shioya	50° 22′.0	January	3	5h 6m.4	p.m.
	50° 25′.5	„	„	6 16.5	„
	50° 23′.2	„	4	8 14.2	a.m.
	50° 26′.5	„	„	11 7.1	„
	50° 25′.3	„	„	2 48.7	p.m.
	50° 26′.5	„	„	5 58.3	„
	50° 26′.8	„	5	9 9.7	a.m.
Isshiki	48° 18′.8	„	8	10 51.4	„
	48° 19′.0	„	„	0 40.7	p.m.
	48° 14′.4	„	„	3 2.5	„
	48° 18′.7	„	„	4 29.8	„
	48° 15′.0	„	„	5 20.2	„
	48° 16′.5	„	„	5 54.2	„
	48° 16′.7	„	9	8 23.9	a.m.
	48° 14′.3	„	„	9 53.1	„
	48° 17′.2	„	„	4 12.2	p.m.
	48° 17′.1	„	„	4 48.9	„
	48° 16′.2	„	„	5 31.2	„
Shimizu...	48° 37′.4	January	11	0 34.6	p.m.
	48° 36′.9	„	„	11 3.2	„
	48° 37′.3	„	12	8 30.9	a.m.
	48° 37′.0	„	„	10 29.7	„
	48° 36′.6	„	„	1 9.2	p.m.
	48° 37′.4	„	„	4 43.1	„

Horizontal Force.

Station.	Horiz. Force.	M.	Temp.	Date & Hour. (L.M.T.)
Numazu	0.30115	674.67	23°.03	Dec. 21 0ʰ 0ᵐ.7 p.m.
	.30073	677.54	14°.65	„ „ 4 45.8 „
	.30119	678.00	11°.09	„ „ 8 48.3 „
	.30089	679.72	8°.20	„ 22 7 48.5 a.m.
Hachiman-mura... near Hamamatsu.	0.30148	678.36	10°.73	„ 22 5 57.9 p.m.
	.30080	679.64	8°.25	„ „ 9 44.0 „
	.30116	677.77	11°.69	„ „ 3 41.3 „
	.30171	678.50	6°.85	„ „ 10 42.1 „
	.30188	677.83	6°.81	„ 24 8 56.8 a.m.
Nagoya	0.30148	677.85	4°.80	„ 24 6 45.0 p.m.
	.30107	675.60	9°.10	„ 25 9 28.2 a.m.
	.30136	672.16	16°.43	„ „ 11 45.0 „
	.30119	670.86	16°.23	„ „ 0 40.7 p.m.
	.30160	671.03	16°.12	„ „ 1 33.9 „
	.30122	671.93	14°.84	„ „ 2 21.4 „
	.30098	673.32	11°.13	„ „ 4 17.6 „
	.30131	675.06	8°.00	„ „ 6 47.6 „
	.30109	675.90	7°.53	„ „ 10 18.2 „
	.30120	676.44	6°.49	„ 26 8 45.1 a.m.
Nagahama	0.30081	672.13	13°.26	„ 27 1 13.4 p.m.
	.30100	674.83	9°.97	„ „ 6 10.2 „
	.30065	674.79	8°.54	„ 28 9 13.3 a.m.
	.30098	672.61	12°.23	„ „ 1 50.0 p.m.
	.30078	660.97	8°.73	„ „ 4 51.8 „
	.30096	662.43	3°.63	„ „ 10 1.8 „
Obama	0.30166	655.18	16°.66	„ 30 1 37.5 p.m.
	.30210	658.42	12°.03	„ „ 4 59.0 „
	.30268	655.42	12°.03	„ „ 9 57.1 „
	.30134	654.74	16°.72	„ 31 9 13.8 a.m.
Shioya	0.29648	658.96	6°.17	Jan. 3 9 4.8 p.m.
	.29696	659.01	8°.11	„ 4 7 11.9 a.m.

Station.	Horiz. Force.	M.	Temp.	Date & Hour. (L.M.T.)
Shioya	.29665	656.58	10°.99	Jan. 4 0h 11m.9 p.m.
	.29646	656.81	10°.79	„ „ 1 57.0 „
	.29650	657.81	7°.57	„ „ 5 8.4 „
	.29670	658.37	7°.10	„ „ 6 46.5 „
	.29632	659.02	4°.80	„ 5 8 7.6 a.m.
Isshiki	0.30294	656.90	11°.28	„ 8 11 43.5 a.m.
	.30260	657.55	9°.03	„ „ 1 32.4 p.m.
	.30288	657.95	8°.38	„ „ 3 51.7 „
	.30281	657.81	8°.14	„ „ 8 30.9 „
	.30283	660.79	2°.07	„ „ 7 22.2 a.m.
	.30313	658.17	8°.55	„ „ 9 9.5 „
	.30284	656.61	11°.25	„ „ 2 25.1 p.m.
	.30303	659.77	3°.93	„ „ 7 6.2 „
Shimizu	0.30065	653.63	17°.21	„ 11 2 17.1 „
	.30058	654.35	14°.54	„ „ 3 16.1 „
	.30097	659.02	6°.24	„ „ 10 13.0 „
	.30072	657.54	9°.08	„ 12 9 10.1 a.m.
	.30048	656.02	12°.74	„ „ 11 33.1 „
	.30056	655.60	12°.86	„ „ 0 37.5 p.m.
	.30078	656.48	11°.50	„ „ 3 41.9 „
	.30089	658.29	6°.25	„ „ 5 3.6 „

Appendix.

Recalculated values of H for 1887.

Station.	Horiz. Force.	M.	Temp.	M_0.	Date & Hour. (L.M.T.)	
Ishibashi	.29134	937.15	21°.0 c.	944.37	June 23	h 6.00 a.m.
Yabuki	.28952	938.60	20°.4	945.54	„ 25	8.00 „
Matsukawa	.28784	937.78	20°.0	944.60	„ 26	7.00 „
Shiraishi	.28828	936.72	20°.1	943.58	„ 28	7.30 „
Shiogama	.28754	935.41	22°.6	943.21	„ 29	9.00 „
	.28720	933.79	22°.7	941.59	„ 30	6.00 „
Ishinomaki	.28778	936.53	21°.2	943.82	July 1	8.00 „
	.28745	937.28	22°.3	944.50	„ „	5.30 p.m.
Ichinoseki	.28429	936.20	18°.0	942.65	„ 3	7.30 a.m.
Hanamaki	.28036	938.04	18°.4	944.28	„ 5	7.30 „
Morioka	.28179	937.26	20°.8	944.39	„ 6	8.00 „
Miyako	.27899	934.70	23°.2	942.76	„ 8	4.00 p.m.
Kuji	.27986	935.56	23°.4	943.67	„ 10	4.00 „
Hachinohe	.27688	937.02	22°.2	944.69	„ 12	8.00 a.m.
Gonohe	.27624	933.75	24°.3	942.24	„ „	5.00 p.m.
Nobechi	.27579	934.52	24°.1	942.91	„ 13	6.00 „
Aomori	.27731	935.88	22°.7	943.73	„ 15	8.00 a.m.
Hakodate...	.27322	935.75	22°.3	943.19	„ 16	5.00 p.m.
Sapporo	.26768	931.52	25°.2	940.29	„ 19	5.30 „
Kiitup	.26677	933.83	23°.1	941.82	„ 24	4.30 „
Nemuro	.26047	931.86	26°.3	941.07	„ 25	4.00 „
Hirosaki	.27828	932.97	26°.3	942.19	„ 29	4.30 „
Ōdate...	.27741	935.34	20°.3	942.24	„ 31	6.00 a.m.
Nōshiro	.27857	930.85	31°.0	941.89	Aug. 1	4.00 p.m.
Akita	.28285	932.18	25°.2	941.00	„ 3	6.15 a.m.
Kariwano	.28231	934.50	26°.4	943.78	„ 4	6.30 „
Yokote	.28314	932.91	26°.4	942.17	„ 5	7.00 „
Innai	.28229	931.47	28°.0	941.35	„ „	4.30 p.m.
Shinjō	.28530	931.43	27°.4	941.07	„ 7	7.00 p.m.
Sakata	.28472	931.94	27°.6	941.65	„ 8	7.00 a.m.
Yamagata	.28655	932.80	25°.4	941.63	„ 10	7.00 „

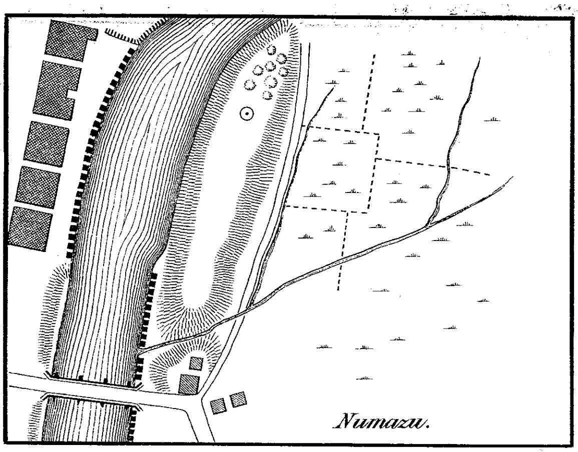
Station.	Horiz. Force.	M.	Temp.	M_0.	Date & Hour. (L.M.T.)
Yonezawa	.28833	931.28	30°.3 c.	942.04	Aug. 11 $5^{h}.30$ p.m.
Oguni...	.28756	933.58	21°.8	941.02	„ 13 7.00 a.m.
Nakajō	.28764	930.23	28°.3	940.20	„ 14 7.30 „
Ebisu...	.28987	923.57	35°.0	936.16	„ 15 noon
Niigata	.28704	928.32	28°.1	938.19	„ 16 7.30 a.m.
Kashiwazaki... ...	.28887	927.66	29°.7	938.17	„ 17 6.00 „
Sekiyama...	.29162	930.36	27°.1	939.83	„ 19 8.15 „
Ueda	.29636	936.59	21°.8	944.06	„ 21 6.00 „
Takanomachi ...	.29531	928.90	26°.6	938.19	„ „ 6.00 p.m.
Kōfu	.29282	926.19	35°.4	938.40	„ 23 4.30 „
Hara	.30146	929.69	25°.0	938.37	„ 25 6.35 a.m.
Hakone	.30514	929.16	25°.4	937.97	„ „ 5.00 p.m.
Ōtsu	.29674	927.19	29°.2	937.45	„ 26 5.00 „
Hōjō	.29641	927.85	27°.3	937.41	„ 28 6.00 a.m.
	.29632	926.75	29°.4	937.10	„ „ 4.00 p.m.
Katsuura...	.29622	929.20	25°.2	937.95	„ 29 5.30 „
Tōgane	.29534	929.22	22°.4	936.87	„ 31 6.15 a.m.
Chōshi	.29701	928.60	27°.0	938.02	Sept. 1 7.20 „
Kioroshi	.29381	930.46	25°.8	938.69	„ 2 7.00 „
Shimmachi	.29380	929.65	19°.0	935.86	„ 25 5.00 p.m.
Ōmiya	.29427	928.92	20°.1	935.73	„ 26 10.20 a.m.
Shimoda	.29992	442.80	20°.7		June 23 10.30 „
下田港海岸	.29992	442.68	21°.2		„ „ 3.13 p.m.
	.29967	440.43	21°.8		„ „ 8.21 „
Shimizu	.30166	441.45	21°.3		„ 25 afternoon
清水港波止場	.30022	442.65	21°.4		„ „ „
	.29971	442.45	26°.0		„ 26 2.10 p.m.
	.30016	440.72	25°.2		„ „ 4.31 „
	.29906	441.21	25°.1		„ 27 8.48 a.m.
Nagoya	.29880	442.17	26°.9		„ 30 9.02 „
名古屋師範學校新築地構內	.29840	441.93	29°.7		„ „ 11.44 „

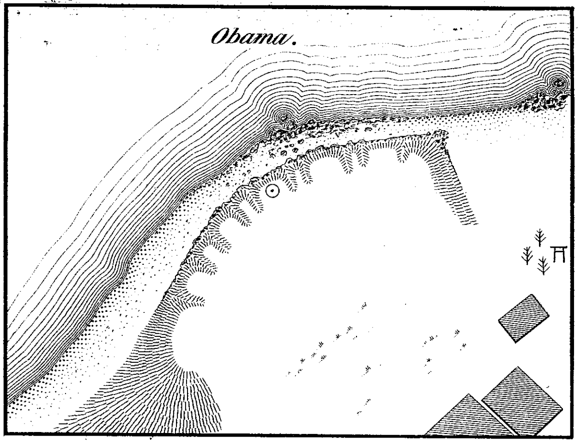
Station.	Horiz. Force.	M.	Temp.	Mo.	Date & Hour. (L.M.T.)
Nagoya (*continued*)	.29988	441.37	24°.2 C.		June 30 6.26 p.m.
Kamiyashiro... ...	.30234	440.84	24°.7		July 4 8.46 a.m.
一色村鹽田中央臺場	.30198	441.15	26°.3		„ „ 11.25 „
	.30199	441.37	24°.8		„ „ 5.25 p.m.
Nagahama	.30064	439.44	26°.8		„ 6 0.53 „
長濱舊城趾湖岸	.30033	440.31	23°.7		„ „ 6.03 „
	.30019	440.07	24°.9		„ 7 9.02 a.m.
Hyōgo	.30268	439.85	29°.3		„ 8 2.07 p.m.
吉田新田和田岬燈臺ヨリ凡五丁西	.30255	440.36	26°.5		„ „ 4.48 „
	.30255	441.80	26°.4		„ 9 9.10 a.m.
	.30338	438.85	31°.6		„ „ 1.20 p.m.
Tokushima	.30731	436.82	27°.8		„ 10 6.51 „
安宅村蜂須賀氏別邸內	.30515	439.84	27°.3		„ 11 9.53 a.m.
	.30543	439.55	28°.2		„ „ 0.10 p.m.
Kōchi...	.31094	435.95	27°.9		„ 17 0.16 a.m.
高知字棒堤	.31043	435.98	29°.0		„ „ 7.48 „
	.30842	438.34	31°.7		„ „ 11.55 „
Minabe	.30437	438.90	31°.6		„ 21 9.57 „
南部北道村字濱端(舊臺場近傍)	.30484	438.51	31°.5		„ „ 11.30 „
	.30486	438.12	32°.8		„ „ 2.55 p.m.
	.30494	438.74	30°.7		„ „ 5.56 „
Okayama...	.30418	438.16	31°.4		„ 26 9.00 a.m.
中野村宗忠神社前新道東端	.30430	437.71	34°.2		„ „ 1.28 p.m.
	.30446	437.86	33°.0		„ „ 5.07 „
Hiroshima	.30713	438.02	34°.15		„ 28 0.41 „
病院付屬地庭中池ノ南岸	.30674	437.82	35°.2		„ „ 4.13 „
	.30734	440.34	25°.0		„ 29 6.32 a.m.
	.30688	440.21	26°.9		„ „ 7.35 „
	.30650	439.45	29°.9		„ „ 8.37 „
	.30683	438.43	34°.15		„ „ 9.32 „
	.30702	437.60	35°.75		„ „ 10.31 „

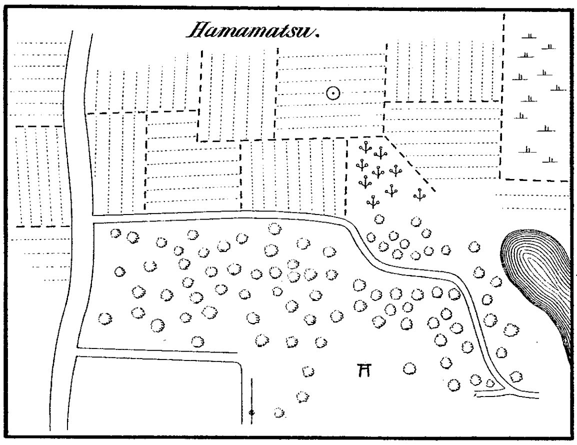
Station.	Horiz. Force.	M.	Temp.	M_0.	Date & Hour. (L.M.T.)
Hiroshima (*continued*)	.30697	437.22	37°.0 c.		July 29 11.35 a.m.
	.30719	437.38	36°.0		„ „ 0.32 p.m.
	.30695	437.37	36°.2		„ „ 1.38 „
	.30716	437.22	35°.75		„ „ 2.32 „
	.30724	437.74	35°.1		„ „ 3.32 „
	.30685	438.44	33°.3		„ „ 4.35 „
	.30711	438.20	30°.5		„ „ 5.32 „
	.30694	439.22	29°.0		„ „ 6.47 „
Wakwan (Korea)...	.30421	438.94	31°.9		Aug. 6 10.06 a.m.
日本人居留地西町四	.30463	438.13	32°.7		„ „ 1.39 p.m.
丁目松林西館	.30472	439.33	27°.6		„ „ 5.19 „
Mēho (Korea) ...	.30667	439.78	26°.8		„ 11 6.34 a.m.
落東江口流中洲	.30592	438.59	32°.8		„ „ 11.01 „
	.30673	436.76	36°.1		„ „ 2.08 p.m.
Pusan (Korea) ...	.30893	437.89	29°.2		„ 13 10.56 a.m.
釜山城北河原	.30915	436.07	34°.3		„ „ 2.23 p.m.
	.30897	437.44	29°.2		„ „ 4.06 „
Kurosaki...	.30605	436.82	32°.6		„ 15 11.24 a.m.
Shiinokijima	.30514	437.83	28°.3		„ „ 6.40 p.m.
Fukuoka	.31011	437.40	30°.5		„ 22 7.44 a.m.
福岡監獄署裏舊臺場	.30988	436.55	32°.5		„ „ 10.40 „
	.30986	435.95	34°.0		„ „ 3.24 p.m.
Nakatsu	.30975	435.53	35°.8		„ 24 1.26 „
中津城北海濱	.30978	436.04	34°.9		„ „ 4.23 „
	.30983	437.69	28°.8		„ 25 8.27 a.m.
Saganoseki	.31086	437.24	30°.7		„ 28 8.23 „
關村伽籃堂跡	.31102	437.06	32°.5		„ „ 11.10 „
	.31146	436.94	30°.4		„ „ 3.37 p.m.
Hichiyamura ...	.31356	436.74	31°.4		„ 29 3.49 „
日知屋村字春町	.31334	438.37	27°.8		„ 30 8.07 a.m.
	.31362	436.70	34°.0		„ „ 10.45 „

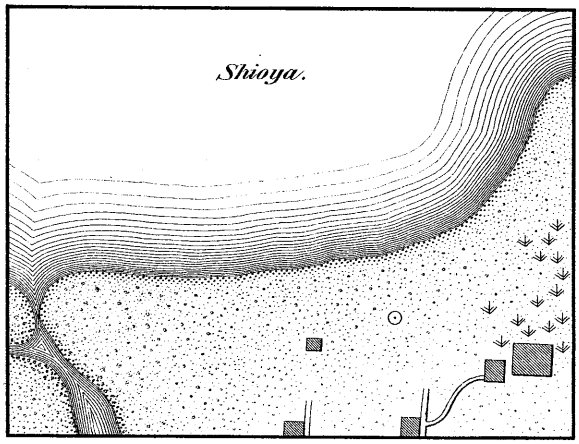
Station.	Horiz. Force.	M.	Temp.	M_0.	Date & Hour. (L.M.T.)
Miyazaki...	.31587	437.30	31°.4 C.		Sept. 1 8^h.53 a.m.
江平町師範學校躰操場	.31565	436.67	32°.9		„ „ 9.31 „
	.31552	436.33	34°.8		„ „ 10.12 „
	.31528	436.20	34°.6		„ „ 10.51 „
	.31512	436.27	34°.8		„ „ 11.31 „
	.31518	436.27	34°.8		„ „ 0.11 p.m.
	.31564	436.33	34°.0		„ „ 1.30 „
	.31569	435.40	34°.5		„ „ 2.10 „
	.31533	436.22	33°.8		„ „ 2.50 „
	.31533	436.45	33°.35		„ „ 3.31 „
	.31588	436.31	33°.15		„ „ 4.12 „
	.31561	436.84	31°.6		„ „ 4.49 „
	.31555	437.20	29°.6		„ „ 5.29 „
	.31521	437.70	28°.35		„ „ 6.09 „
Yatsushiro	.31477	436.52	32°.6		„ 6 10.48 a.m.
八代町陸軍埋葬地	.31496	436.81	31°.8		„ „ 4.20 p.m.
字若宮	.31458	436.42	31°.5		„ „ 9.33 „
Nagasaki...	.31369	436.32	33°.9		„ 10 9.43 a.m.
波止場東巡査講習場					
Hagi	.30857	436.42	32°.2		„ 13 11.20 „
濱崎海岸字菊ヶ濱	.30902	437.03	29°.4		„ „ 0.48 p.m.
	.30874	438.00	26°.1		„ „ 4.18 „
Hamada	.30023	438.14	26°.0		„ 16 4.32 „
原井村市中畑	.30022	440.06	18°.9		„ 17 7.12 a.m.
	.30046	436.68	31°.2		„ „ 11.21 „
Matsue	.29993	437.96	26°.5		„ 20 1.04 p.m.
縣廳裏城内	.30014	437.91	26°.0		„ „ 4.55 „
	.29992	440.25	19°.9		„ 21 7.00 a.m.
Imaichi	.30008	438.14	24°.2		„ 22 8.53 „
今市橋渡村字御前	.30019	437.49	29°.3		„ „ 11.40 „
今市ヨリ西凡十丁	.30018	438.29	23°.7		„ „ 5.14 p.m.

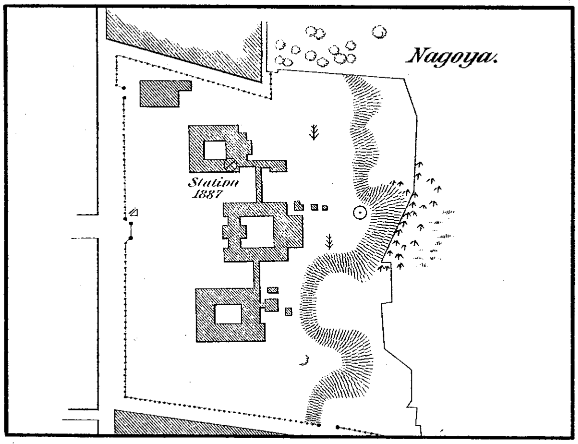
Station.	Horiz. Force.	M.	Temp.	M_0.	Date & Hour. (L.M.T.)
Kanōmura	.30175	439.14	21°.9 c.		Sept. 25 0.09 p.m.
邑美郡叶村字中島河原土堤	.30186	439.31	20°.9		„ „ 4.42 „
	.30120	441.22	14°.7		„ 26 7.20 a.m.
Koyamamura ...	.29971	438.21	24°.3		„ „ 1.51 p.m.
湖山村東北二丁計綿畑	.30971	438.45	21°.9		„ „ 5.07 „
	.30003	438.74	21°.3		„ 27 7.54 a.m.
	.29962	437.16	28°.7		„ „ 10.26 „
Maizuru	.30079	438.27	25°.3		„ 30 11.49 „
舞鶴城趾小學校運動場	.30108	438.92	21°.5		„ „ 4.45 p.m.
	.30118	440.34	16°.8		Oct. 1 7.07 a.m.
Obama	.30006	438.13	24°.7		„ 2 11.34 „
小濱臺場跡	.30047	438.82	21°.2		„ „ 4.33 p.m.
	.30006	440.66	16°.8		„ 3 8.00 a.m.
Shioyaura	.29536	437.82	26°.9		„ 4 0.02 p.m.
鹽屋浦小學校裏一丁計	.29566	437.76	26°.0		„ „ 4.53 „
	.29550	439.00	20°.6		„ 5 7.26 a.m.
Nanao	.29398	440.62	16°.8		„ 8 9.05 „
七尾字出崎加州海軍所跡	.29381	440.13	19°.2		„ „ 0.59 p.m.
	.29424	439.26	20°.6		„ „ 4.33 „
Tōkyō (W)	.29678	438.13	23°.4		Nov. 8 11.52 a.m.
帝國大學運動場	.29661	437.71	25°.4		„ „ 1.39 p.m.
	.29659	439.75	17°.1		„ „ 4.20 „
„ (E)	.29634	438.99	19°.7		„ 10 9.29 a.m.
	.29644	438.66	22°.1		„ „ 1.01 p.m.
	.29619	440.30	16°.8		„ „ 4.15 „

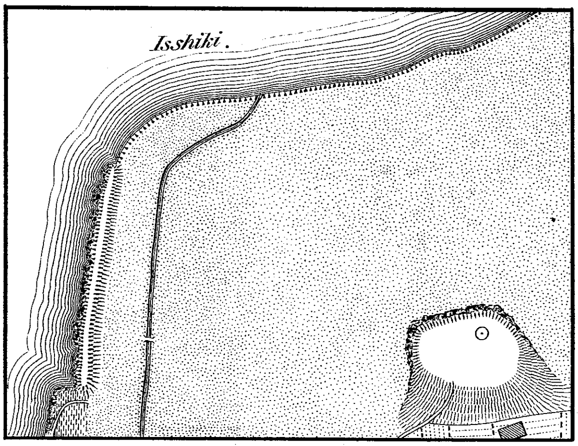


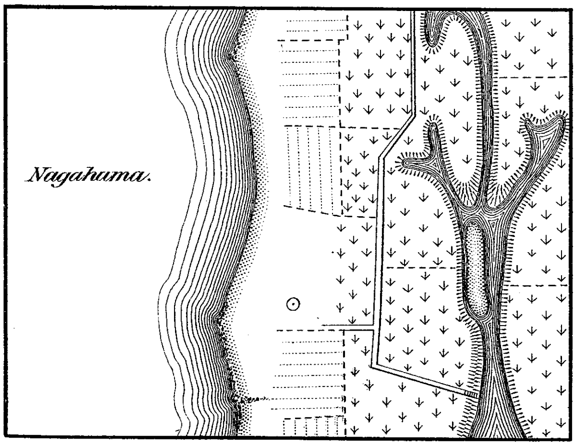


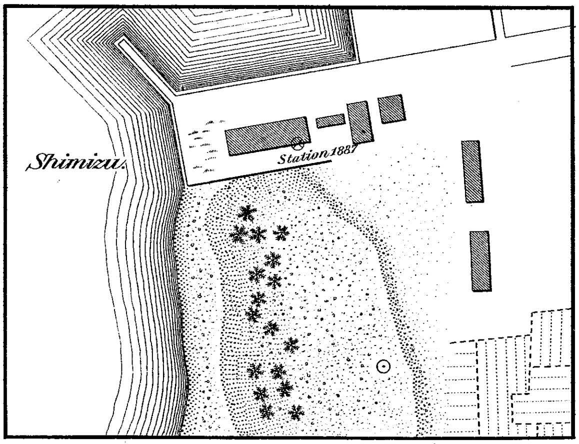












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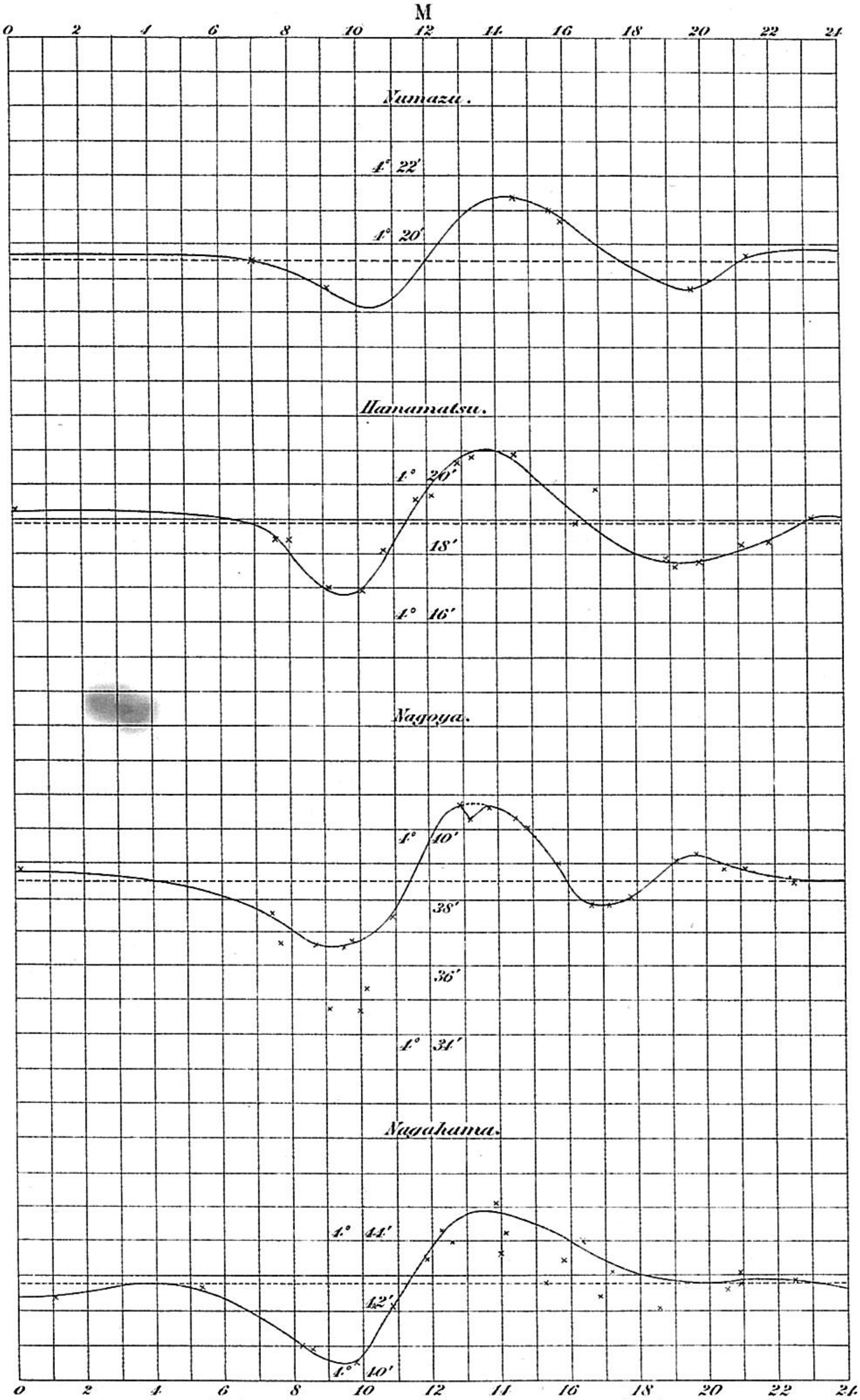

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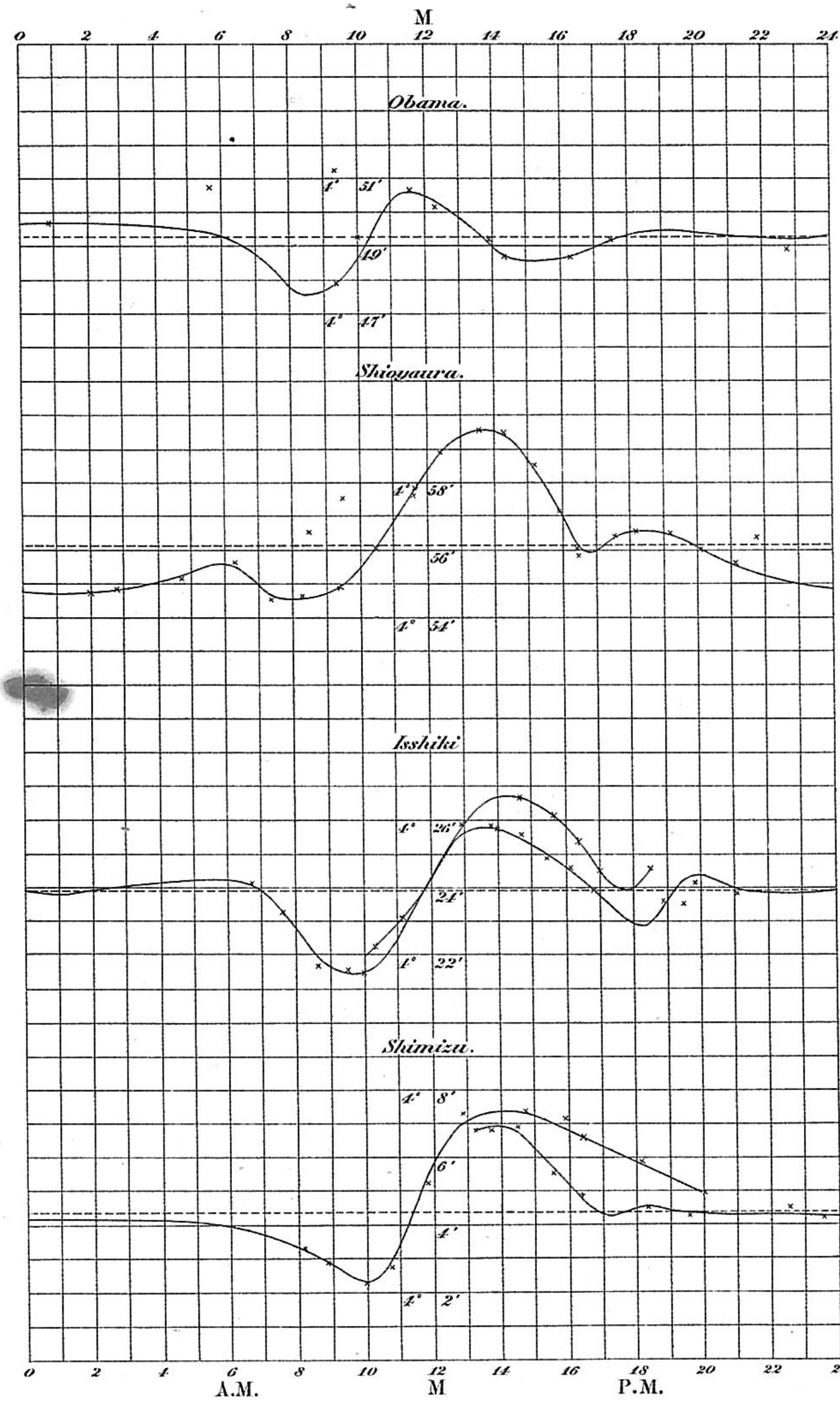

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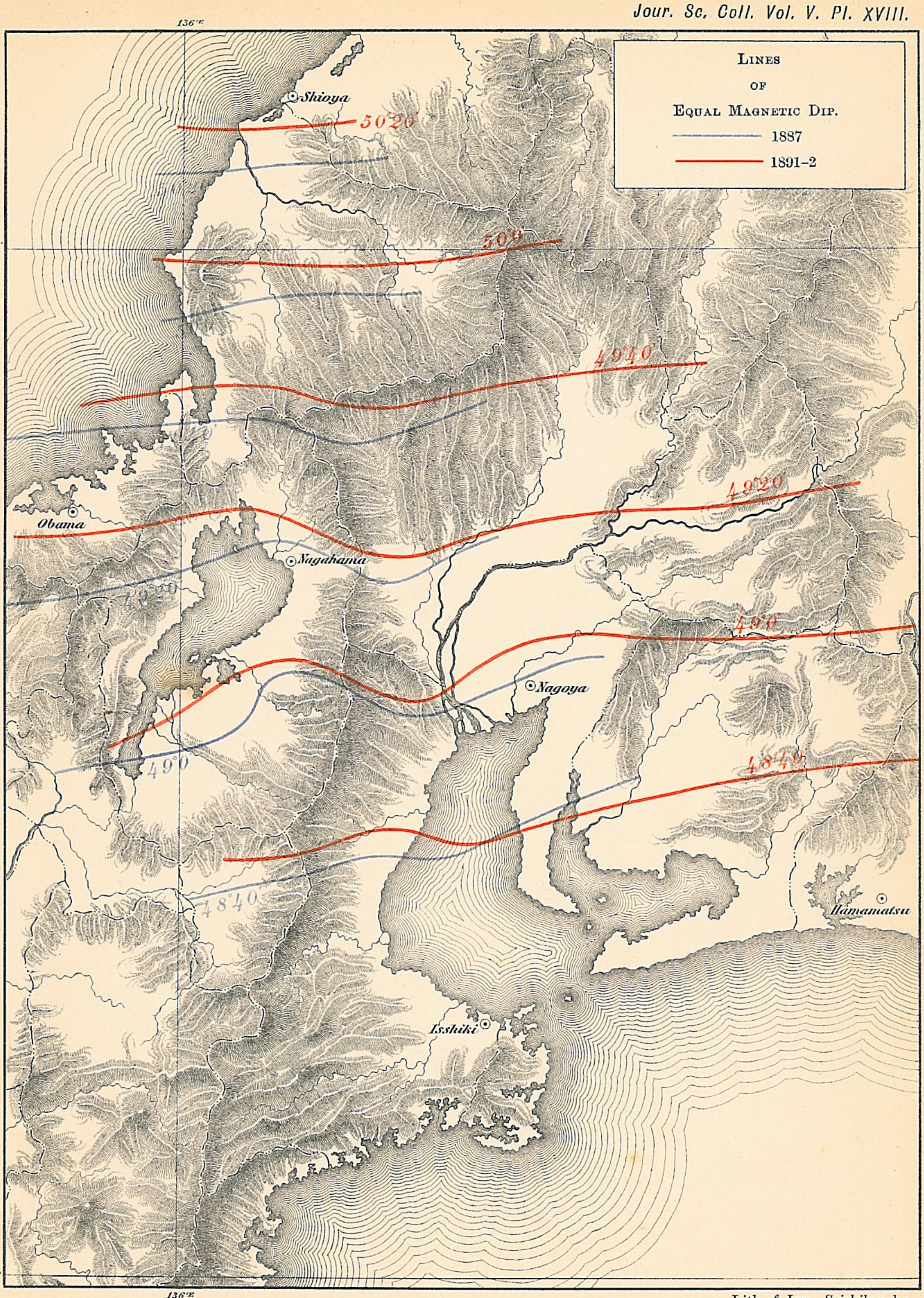

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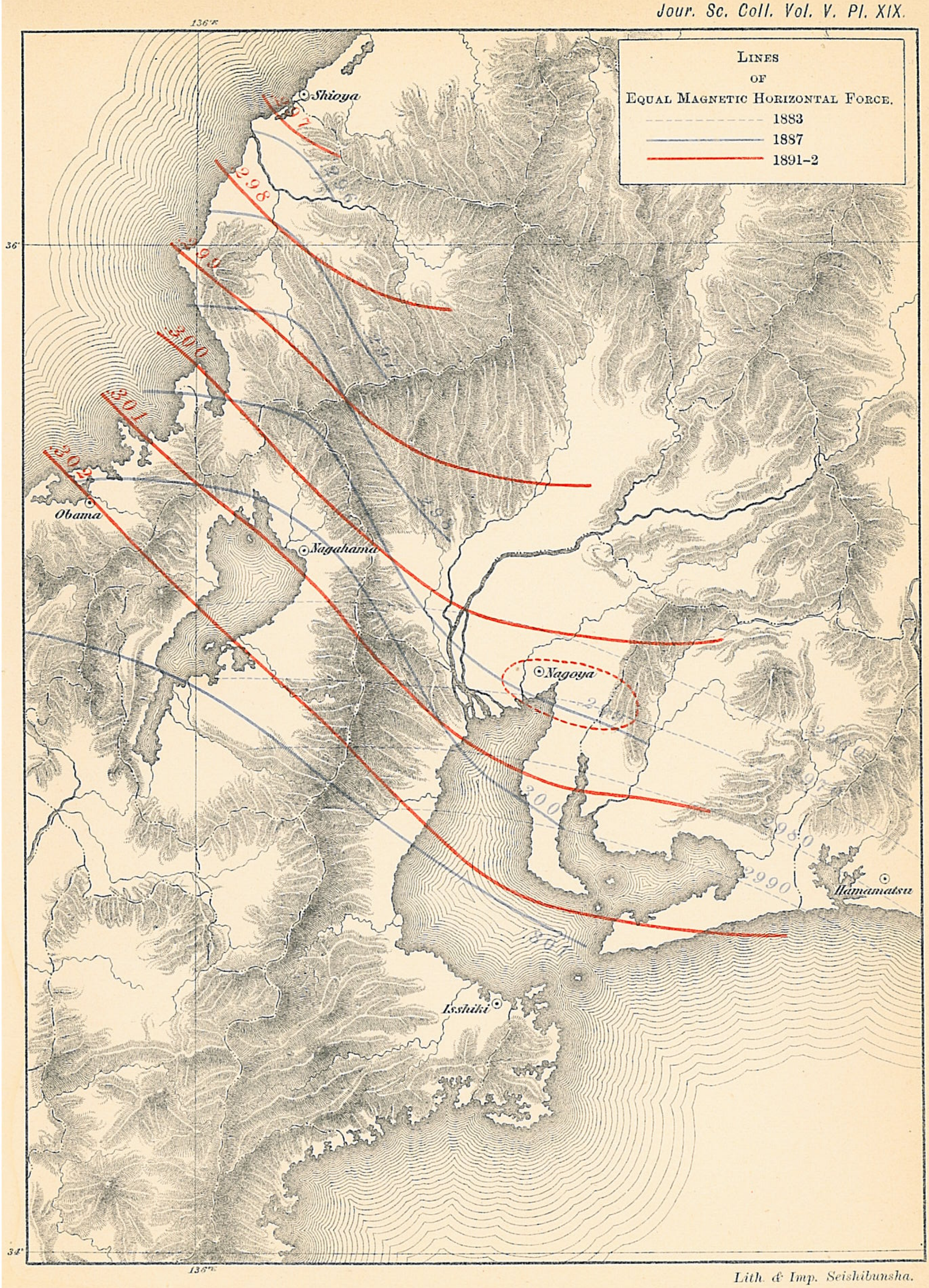

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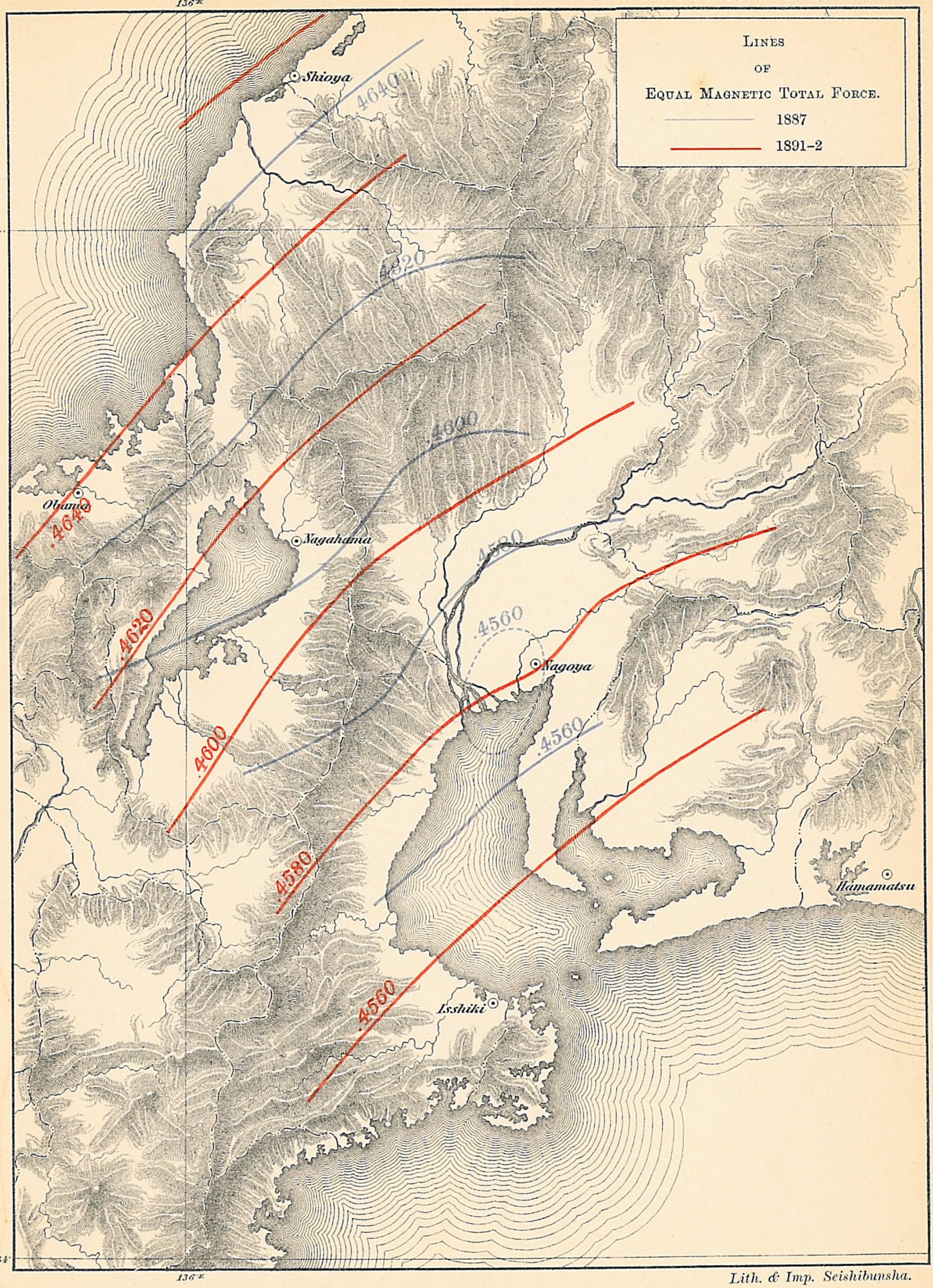

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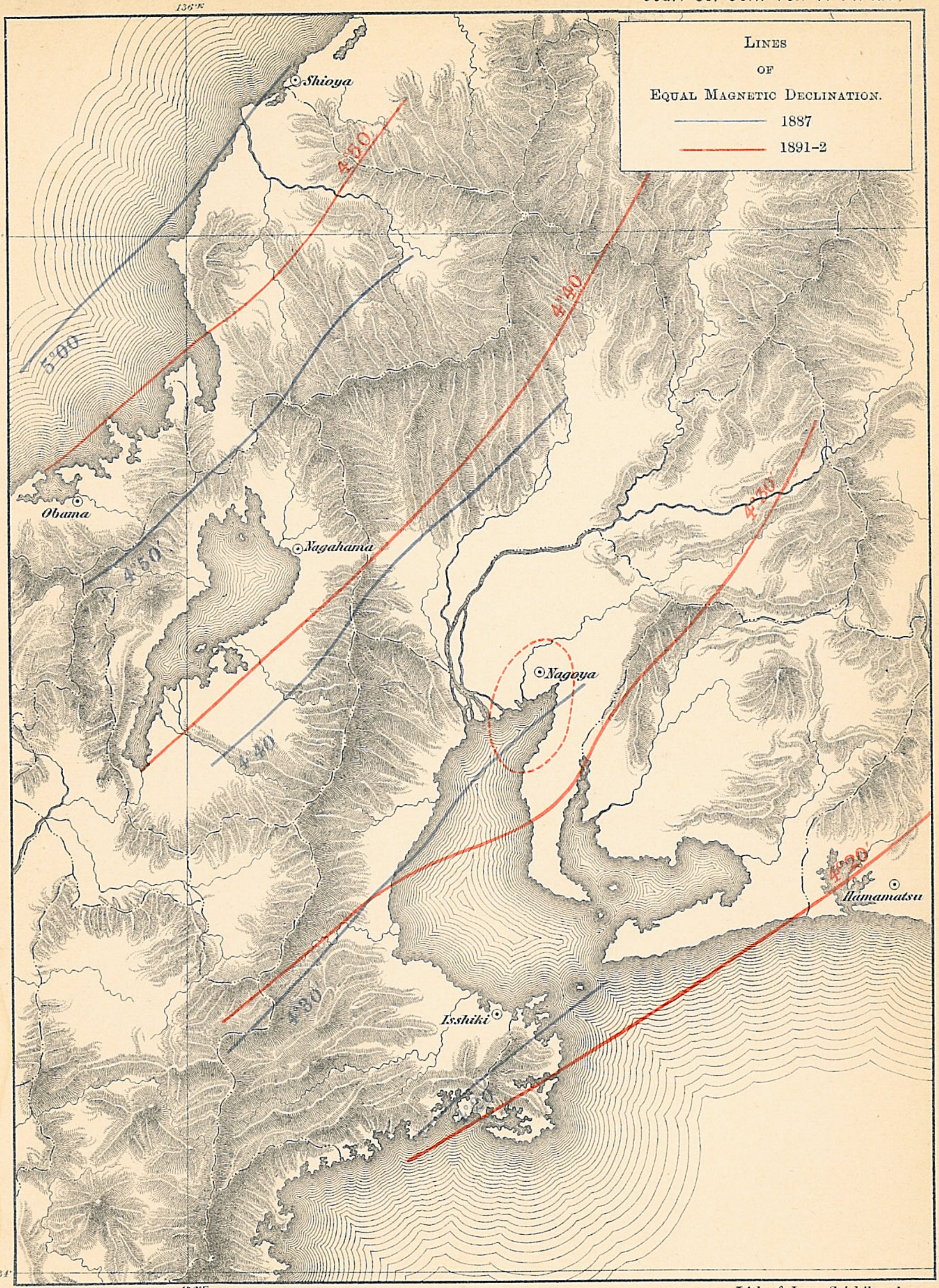

Lith. & Imp. Seishibunsha.