NOTES ON SECULAR CHANGES OF MAGNETIC DECLINATION IN JAPAN.

BY

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[READ MAY 2ND, 1882.]

It is a well known fact that those phenomena which indicate the magnetic force of the earth are subject to changes which show as a rule a certain regularity by their dependence on periods of time. The magnetic declination varies with the seasons and even every hour at one and the same place; there is also a continual secular change. The hourly oscillations of the magnetic needle are mostly regular, i. e. periodical, and these periods are known to be dependent upon the position of the sun. At night-time the needle is almost stationary, but with sunrise it commences to move, and then continues this motion until about noon, after which it again moves gradually back to the original position. Irregular (non-periodical) movements of the needle may have something to do with earthquakes and volcanic eruptions. Of the secular changes of declination the most complete series of observations has been made at Paris. Here the declination amounted to 8°10′ E. in 1550, then increased to 11°30′, which value was reached in 1580; after this a decrease took place, it became 0° in 1663–1666, turned West and gradually increased in this direction up to the year 1814. At this time it had obtained the value of 22°34′, and now commenced to move back in an easterly direction, but with considerable irregularity. It is, as far as I know, completely unknown to what causes these secular oscillations of the needle can be attributed, mainly because the material at our disposal does not extend over a sufficient length of time to form any valuable judgement upon these difficult questions.

Therefore I do not hesitate to bring the scanty results of some investigations on the subject before this society, though I must apologize for offering my observations in a very incomplete and rough state. This may perhaps be a good occasion to call the attention and the interest of this society to a subject which must be no doubt of highest importance for seismic science, and I hope that some one who is more conversant with the subject than I may soon show whether there is, or is not, an intimate connection between magnetism and volcanism, and where this connection exists.

Unfortunately the number of magnetic observations in Japan is very limited indeed. It is true that the coast of Japan is pretty well surveyed, and the magnetic variations so important for the mariner are given on published charts, but by a comparative investigation of these data it can be seen that many of the observations appear to be inaccurately determined, if their applicability to scientific purposes is considered, and, on the other hand, these observations are scattered over a large number of years. They are however the only source by which we can construct the present magnetic meridians of Japan. I have tried to make out on the map the courses of the 4° W. and 5° W. meridians. Rough as the curves determined in this way may appear, it can be seen that they follow a crooked line, and that their course appears to conform to certain lines peculiar to the configuration of the Japanese Islands. Materials for constructing even approximately the isoclines and the isodynomical lines are completely wanting, as the magnetometer measurements that have been made only relate to a very small part of Japan. These more scientific determinations were undertaken during the two last years for the geological survey and their results have been published in the *Mittheilungen der Ostasiatischen Gesellschaft.*

In order to compile in the shortest time possible a general topographical and geological map of Japan, and for the purpose of getting the means to provide the surveyors later on with instructions relating to local specialties, I had decided from the very beginning of the geological survey to carry out myself a reconnaissance of the whole country. This

work I commenced in the beginning of last year, being helped by a few assistants. During 4 months time almost uninterrupted flying surveys had to be made (besides 1 month devoted to the geological Survey of Aui), the total length of the route surveyed by myself being about 400 *ri.* Extensive observations were made both on the geology and on the topography of the country, which entailed an elaborate use of the magnetic compass. Joining the material collected on these excursions together with that represented by the *Chissoku Zenkoku Chiudzu,* made in 1800–1819, and known as Ino's map of Japan, I am enabled to compile a map which will at least correctly show the general features of the country. Mr. Knipping has published in the *Mittheilungen der O. G.* very favorable remarks as to the accuracy of Ino's map, and I took occasion to convince myself that the *Chissoku Zenkoku Chiudzu* is sufficiently correct to be used as a basis for the reconnaissance map of the Geological Survey.

Ino's map contains a great number of compass measurements. These are given in Japanese characters, and the total sum of all the angles laid down in the map in this way amounts to not less than 2040. Comparing the magnetic azimuths as given by Ino with compass measurements of exactly corresponding directions as determind by the Reconnaissance, it can be shown, as I shall endeavour to prove, how much the magnetic declination has changed since Ino. Ino's field books have unfortunately been lost by the burning down of the Uyeno temples in 1868; different essays written by him are likewise no longer in existence, and the map edited in 3 different scales and some record books accompanying this map are all that have been preserved. This map gives a means for the determination of the course of the isogones for the beginning of this century. Possibly the completion of a map, showing the system of the isogones for Ino's time and the accurately determined system of the present isogones, isoclines and isodynamical lines, may in future lead to a better understanding of the causes of the secular oscillations of the needle. I need scarcely point out that continued studies in this direction promise the more, as Japan mainly extends in a North and South direction, and is therefore

especially fit for magnetic studies; and further, because we have to do with a country which, as history tells us, had periodically a very high volcanic activity; besides Japan might deserve the special and prominent attention of those who are interested in magnetic studies, as it is part of a magnetic island on which the declination is West. The dependence of many of the magnetic phenomena on electric currents moving round the earth may be considered as probable. In consequence we may perhaps expect the existence of a connection between magnetic phenomena and certain internal conditions of the earth, as the earth itself will have its electric currents, and these currents ought to be influenced by internal changes.

In 1870 the *Daigaku* wisely undertook to publish Ino's maps together with his record books, which latter also contain some prefaces and introductions, partly by Ino himself, partly by his colleagues.

Mr. Sekino has, according to my advice, translated the text accompanying the maps, and from his translation I quote the following words of Takahashi Sakuzaemon: "Now the maps have been completed and in place of Ino Tadayoshi, who died before the maps could be published, I myself state the following: The Europeans say that the compass needle generally declines to the West, not pointing due North, and that this variation increases or decreases. Ino Tadayoshi had no better instruments then the common magnetic compass. In Europe these instruments are made with great perfection. Ino, however, did not use any foreign made compass, he on the contrary prepared himself compasses of different kinds. He discovered that the bearings taken with his own compass were always the same, and saw the needle point due North quite constantly, so that anything like the variation of the compass needle was never noticed. From these results he determined that by careful and proper workmanship instruments of the greatest delicacy can be made, and that any piece of iron has much influence upon the needle, deviating it more or less from pointing true North and South. If any one would re-observe the bearings of any places on the map with the common kind of compass, it would most probably give some difference."

Ino obviously overlooked the magnetic declination, because at his time the meridian of no declination passed through Japan. He was therefore right to a certain degree, except of course in his opinion of the greater perfection of his own instrument. Still one might be astonished that he who was so well versed in determining the latitudes with almost absolute accuracy, neglected those larger declinations which at his time appear to have existed in several parts of the country. The reason of his neglecting the smaller declinations is very easily understood. His compass was, as it appears, too roughly divided, and did not show more than 240 divisions, so that the smallest division of his compass would correspond to $1\frac{1}{2}°$ of the proper division. Besides this, Ino's compass must have possessed a certain error due to the non-congruence of proper and magnetic axes of the needle. It will not be possible to determine the amount of this error, without getting the compass itself. Repeated inquiries about this compass of Ino gave again and again a negative result; still I consider it possible that it has been preserved, and take the liberty of inviting the members of this society to assist in its discovery. The just described error of the compass is a constant one, and cannot therefore influence the general results derived from a comparison between Ino's bearings and the present bearings. Besides the said error, there is still another one, caused by friction. Ino's readings may be considered to have an accuracy of about one degree. This is by no means inconsiderable if Ino's bearings are to be used for the determination of the isogones at his time. But it must be borne in mind that the value of the whole investigation cannot be destroyed by this objection, as this unfavorable circumstance is counterbalanced by a favorable one, namely, by the *great number* of the bearings given in Ino's map. In the Northern part alone, in which I travelled last year, and only for this part did I try to determine the change of magnetic declination, there are not less than about 80. Moreover, a profound study and a careful examination of the map leads to data which do not depend on the bearings given, but on bearings measured in the map, and therefore by carrying the work to the greatest possible extent

one ought to arrive at a point not very far from the truth.

The methods applied to determine the magnetic variation at Ino's time are as follows.

1. Such bearings of Ino as are given in numbers on his map are compared with bearings measured during the reconnaissance (prismatic compass). The difference between both is determined; the present magnetic variation was taken from charts or approximately ascertained, and subtracted from this difference. + signs have the meaning declinations E., — signs indicate a declination W. This method is illustrated by the accompanying diagram, Fig. 1, of which the following is the explanation.

NS, Astronomical meridian.
P, Mountain sighted.
M, present position of needle.
M_1, position of needle at Ino's time when declination W.
M_2, position of needle at Ino's time when declination E.
Declination at Ino's time $= \alpha - \beta - \varepsilon$ (West) or
$= \alpha - \delta - \varepsilon$ (East).

2. Sightings taken during the reconnaissance have been compared with the directions of the corresponding lines of Ino as determined by measurement on his map.

This method can be applied only in such cases where the station is determined by Ino and the sighting taken not far away from one of Ino's sightings which bears to the same point. From this the declination was determined as before.

3. Some of the more prominent peaks in Ino's map (Taihezan and Ganjusan) are not in the proper position on account of Ino's overlooking the declination of the compass. The proper position of these peaks was determined in Ino's map, and the difference of Ino's given direction from the direction to the newly determined point measured. The value obtained corresponds approximately to the magnetic declination at Ino's time, as illustrated in Fig. 2, explained as follows:—

I, Direction given by Ino.
P, new position of peak.
β, angle given by Ino (small correction applied).

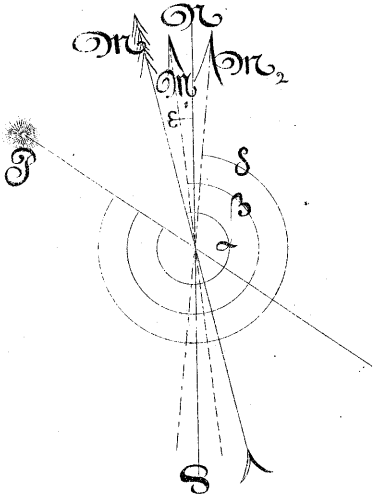


Fig. 1.

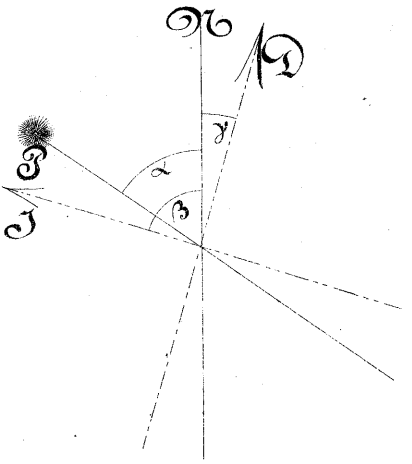


Fig. 2.

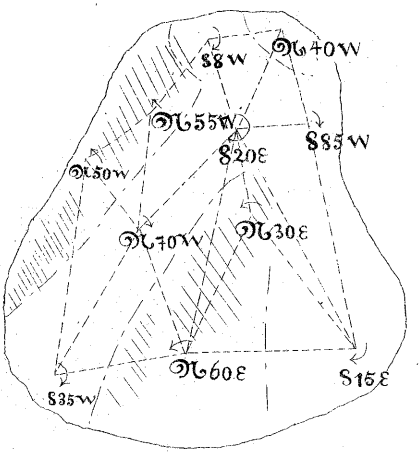
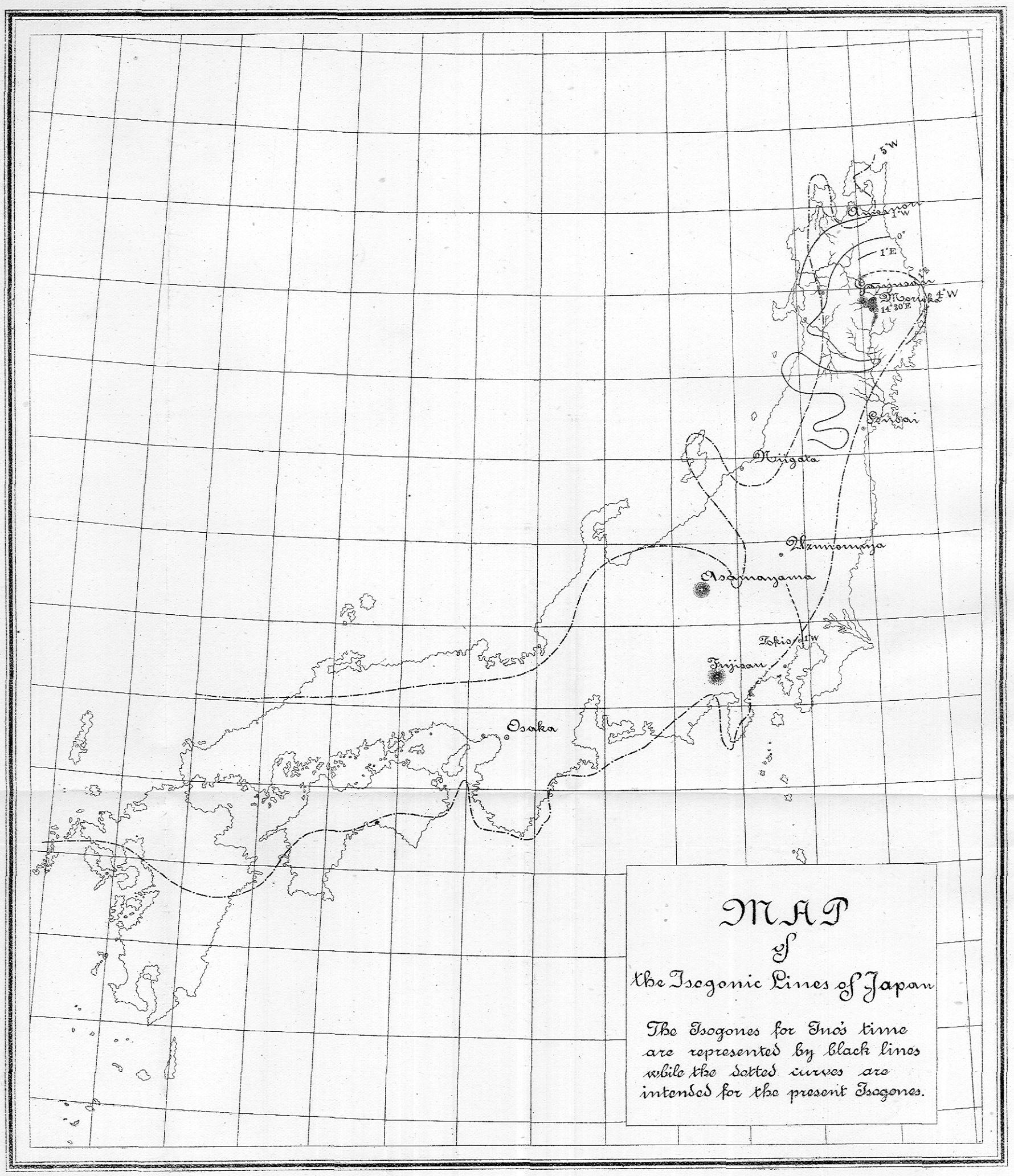


Fig. 3.



MAP
of
the Isogonic Lines of Japan

The Isogones for Tno's time are represented by black lines while the dotted curves are intended for the present Isogones.

α, angle measured from map, between newly determined direction and true meridian (true azimuth of direction to peak P, determined approximately by mapping).

D, Direction of magnetic meridian at Ino's time.

$\gamma = \beta - \alpha =$ approximate declination at Ino's time.

5. All those field sketches forming a connection between two stations contained in Ino's map were put together, the straight distance of the stations and the magnetic azimuth of the connecting line were measured, and the results obtained compared with the corresponding lengths and angles in Ino's map. Though the differences of direction procured in this way can not be used for ascertaining the former magnetic variation at the single localities, it is worth notice that the average of the deviation from Ino's directions very nearly corresponds to the probable average increase of the declination since Ino, as derived by application of the methods mentioned before.

Before commencing a discussion of the tables, and of the curves shown on the accompanying map of Japan, I have to remark that the error of the prismatic compass which I made use of, has not yet been determined sufficiently, and that the graphic exhibition of my results can only be taken as a rough sketch.

Most likely it was first at Tokio that Ino was led to the conviction of the great exactitude of his compass on account of its constantly pointing to the true North. For this reason it must be of special interest to measure those directions to distant mountains, which he determined from Tokio. His map contains a great number of red lines diverging from a point at Fukagawa. Mr. Shiraishi selected a point at Fukagawa which must have been very near to Ino's station, if not coinciding with it, and determined the present magnetic azimuths of a number of these directions. All could not be taken, as the weather has been very unfavourable during the last months. The average value of the former declination obtained from these observations is 1° 2′ W. One might have expected a number smaller than this; possibly the just mentioned value will be reduced by subtracting the error of the prismatic compass used. Properly the single values indicating the change of the magnetic

variation ought to be the same, but every difference obtained from any direction differs from the others. The extreme values are even not less than 2° from each other. This appears to prove that Ino's readings were indeed somewhat roughly taken.

I am able to state however with absolute certainly that the meridian of no declination must have passed through the country at Ino's time. Those old bearings which I tested were taken by Ino during the years 1800 and 1801. Berghaus's *Physikalischer Atlas* contains a map of Erman showing the isogones for the years 1827—1831. Here the 1° W. meridian can be seen to pass through the Eastern part of Yeszo, and to cut off some peninsulas on the Eastern coast of the main island. This gives roughly an average increase of 5° from 1800 to 1881, and of 3° from 1830—1880. According to the values given in charts of one and the same harbor, but relating to different years, we obtain for middle and Northern Japan,

Nanao, 1870—1879 magn. decl. increased from 4° 35′—5° 10′, 35′ in 9 years, or 4′ annually.
Miyadzu, 1867—1879 magn. decl. increased from 4° 30′—5° 15′, 45′ in 12 years, or 3.8′ „
Awomori, 1870—1874 magn. decl. increased from 4°—5° 20′, 1° 20′ in 4 years, or 20′ „

The first two of the values determined very nearly agree with the average annual increase according to Ino's and Erman's observations. On some of the charts the magnetic variation is said to increase about 1′ annually; but this is certainly too little.

While in Northern Japan the magnetic declination certainly increases, it seems according to some charts that it decreases in the South.

If the values for the declinations at Ino's time are put down in a map of Japan and the curves are constructed, the meridian of no declination is seen to pass in a very irregular way through Northern Japan, its longest axis being contained in a median zone of the Island. The West and East declinations are divided left and right of this zero meridian, a result which proves the reliability of the whole process. Strange to say we obtain a very large East declination for Morioka, or the neighbourhood of Ganjusan, and other observations taken in this

region point out that there was at Ino's time a kind of magnetic island in Northern Japan, with some place near Ganjusan as a centre. A Westerly increase of declination since Ino, amounting to about 19°, is so abnormal that one might rightly expect misreadings or something of that sort to have been committed either by Ino or by myself. But repeatedly examining Ino's plottings I always find

1st, that Ino gives N. 60° W. as the bearing of Ganjusan taken from Uyeda near Morioka.

2nd, that this given bearing agrees with the angle measured in the map.

3rd, that however Ino's position of Ganjusan is certainly wrong, as the mountain is more to the right if seen from Morioka.

4th, that the considerable deviation of Ino's bearing at Uyeda is not the only exception, but that the direction given by Ino for the line Sanbonyanagi Ganjusan (N. 45° W.), does not differ from the corresponding direction measured on the map, but from the newly determined point for Ganjusan (N. 33° 50′ W.) about 11° 10′.

Besides, the declinations for Tokudamura and Minami-hidzume (still more South), the former having 6° 50′, the latter 4° 45′, and lastly Ishiboriza, showing an East decl. of 4°, are all abnormal. These larger East declinations follow each other very regularly, becoming the larger the nearer they come to the place of largest Eastern declination. I can not consider it possible that all these large deviations should be accidental, and I am myself nearly convinced that there has been at Ino's time an irregularity in the isogonic system in the immediate neighbourhood of Ganjusan. Whether this irregularity had any connection with the volcanic seat of the just mentioned volcano, I am of course perfectly unable to say; but certainly the close neighborhood of an abnormal magnetic centre and what may be called an active volcano deserves our attention. According to my knowledge there was no volcanic eruption nor any big earthquake in the regions near Ganjusan at the time of Ino, though a very big subterranean noise was noticed in 1823, which is said to have come either from Ganjusan or from

another mountain near it.

One might not believe that Ino could overlook deviations of the compass needle amounting to not less than 14° 30°, but it must be borne in mind how persistently Ino held to his idea of the great superiority of his compass. On the other hand, Ino's work had to be carried through against so many difficulties as to make even that error excusable. He states himself that the survey from Noheji to Sendai offered special difficulties on account of the weather having been unceasingly rough and snowy.

To be free from reproach I shall not conceal a few results which do not confirm the just described magnetic irregularity. The difference of Ino's direction Morioka-Hannamaki and that determined by a survey of Mr. Fujitani gives 4° 45′ W. for Ino's time. Further, the examination of Ino's bearings to Hayachine-san from a few stations on the Oshiukaido, under application of method 3, gives 3 west declinations of 2° 15, 2° 30 and 1° 40′. Since not much weight can be given to the angles found by a flying survey, simply because the amount of error depends upon too many varying circumstances, the 3 last values are likewise of inferior importance. The position of Hayachine in Ino's map namely was determined by very acute angles, so that it came by far too much East.

As stated before, the old declination of Tokio was determined to be 1° 2′. The meridian of 1° therefore took its way probably straight across the island approximately in the direction of the astronomical meridian, setting aside the smaller curvatures. Such magnetic curves would have shown quite a different shape at Ino's time from the present.

Before concluding this paper I may be allowed to add an interesting observation which I was fortunate enough to make on the top of Moriyoshisan, an old volcano near the Ani coppermines, Akitaken. East of the highest point of this mountain lies a small flat covered with dwarf pines and large blocks of lava. At the eastern border of this place I found a block consisting of *exactly the same material* as the surrounding ones, showing very strong magnetism. The block, consisting of granular *Augitetrachyte*, measured about 1.90 met—1.50. By

none of the blocks in the neighbourhood could any effect upon the needle be observed, while the one in question made it revolve very decidely, so that the needle described an arc of 155° in some cases. Standing upright on the block, I could not observe more than a very slight deviation; but lowering the compass, the needle was seen to move very decidedly. The degree of deviation was found to be very different at different points.

The accompanying sketch, Fig 3, shows the distribution of magnetism. The angles given in the sketch are the bearings taken from the single points to a certain mire whose proper bearing was found to be N. 68 W.

The sketch shows the amount of deviation at different points of the surface and in what direction the needle was turned. The East deviations are divided into two zones which cross each other; on the islands cut out by these zones the deviation is to the W. Fragments broken off had a very distinct polar magnetism. It may be that the magnetism of the block was caused by lightning.

In taking observations with the compass, errors may be experienced by the influence of magnetic masses or blocks. But these accidental sources of magnetism may be easily discovered with even little attention. On the top of volcanic mountains it is always necessary to take the sightings from a number of points. I mention that Mr. Knipping observed a very considerable deviation on the top of Nantaisan. Comparing my bearings taken from the top of Chokai at different points, I found that they differed very considerably.

The above notes do not pretend to be anything more than a kind of programm or introduction for an investigation which will extend over a great number of years. The magnetometer observations of the geological survey will successively be carried out through the whole country, and in the course of the said survey all the bearings laid down in Ino's map will be practically tested in the field. This will lead to the construction of magnetic maps both for the present time and for the beginning of this century.

DISCUSSION.

Mr. Knipping said: —

With regard to the curves of equal magnetic variation, for the present and for Ino's time (1802-1819) as charted and explained by Dr. Naumann, I am of the opinion, that the observations do not justify some of these curves, at least not throughout their entire length.

The 5° W. curve for the present time follows almost the coastline of Aomori bay in its various bends and different directions; at Niigata it trends out to sea, making a large angle with the previous direction; it encloses Sado island and then returns far into the interior of the main island, forming at Sado an acute angle; from the interior it runs out to sea again off Etchu.

The 4° W. curve of the present time follows the coast line of Kii peninsula at sea in a S.S.W. direction, turns round Oshima, parallel to the coast line, runs up Kii Channel, about N.W., and turns off Awaji to the S. and S.W. again, all within a radius of about 60 to 80 nautical miles.

On no variation chart, based on a sufficient number of observations, have I ever noticed similar irregularities. If account was taken of the probable error in the observations, and of the fact, that in nautical charts, which Dr. Naumann has consulted, the variation is often given at sea in places where no actual observations were taken, solely for the convenience of the mariner in using the chart, and that in many cases the data are approximate only to 20′ or 30′, all these irregularities would disappear.

The line of no variation for Ino's time resembles in the interior, latitude about 37-38° N., an S flattened down considerably in its lower portion; but this extraordinary shape, which one will look for in vain in a reliable variation chart, similarly disappears, if a probable error of 0.5° to 0.7° is allowed for.

In general, curves can only be accepted as fairly representing what they are intended for, when many observations are at our disposal, not only *on* the curves, but also *between* them.

Whether curves are fair or not, can be further easily tested thus: if two persons, independently, draw by means of the same data the same or nearly the same curves, then the latter may be taken as fairly representing the observations, but in the present instance it is evident, that this test would give unsatisfactory results.

The discovery of Dr. Naumann, that near Morioka in Northern Nippon the variation at Ino's time amounted to 14° E. and decreased gradually to 0° towards the N., W. and S., within a radius of 80 or 100 nautical miles from this point, is highly interesting and important. *A similarly quick change of the magnetic variation, distributed over such an area as the one shown on the chart, is until now only known near the magnetic poles.* It is thus to be hoped, that Dr. Naumann will publish in full all the observations on which his curves of equal variation for Ino's time are based, so as to leave no doubt about the correctness of his results, and also the variation, as found by himself at places near Morioka, because it is highly improbable, that a local magnetic disturbance of such magnitude and extent, as stated for these regions and Ino's time, should have entirely disappeared in 70 or 80 years.

Dr. Naumann replied:—

If Mr. Knipping would take the trouble of re-examining my paper, he would find again and again remarks which point out how little value is attributed by myself to the smaller sinuations of the isogonic lines represented in the map. This map, which I introduced as a "rough sketch" only, is intended to be a mere illustration to my notes. Notwithstanding, Mr. Knipping is attacking in the first line the details of the "sketch"; he even describes the course of the curves very exhaustively and in this way makes up for a deficiency of my paper. I myself have failed to give anything more about the present curves then a short remark about their crooked character, and the "apparent" conformity to the configuration of the Japanese Islands.

Regarding the Sado sinuation of the 5° W. curve, described at length in the foregoing part of the discussion, Mr. Knipping is not aware of the more accurate determinations forming the

basis of this part. Just for the construction of the said sinuation I was able to make use of about 10 declination values, partly determined by magnetometer measurements, partly established by surveyors of the triangulation of Japan. Those declinations given far out at sea, whose localities could not be fixed approximately, were entirely neglected. I mainly used the special plans and charts of the harbors and bays. For the Idzu curve a greater number of chart declinations and also some magnetometer declinations were employed. That the Sado sinuation was founded on something else than on mariners' observations alone, could be decided without a knowledge of the notes to which the sketch belongs, as the said sinuation goes very far inland. It can be seen from these remarks that Mr. Knipping's assertion: "*all these irregularities* would disappear if account was taken, etc." is *entirely without foundation.* It may be that the special character of many sinuations is incorrect, that this special character will experience substantial changes at a time when a greater number of accurate observations shall be at our disposal, some of the sinuations may even disappear, but certainly not all will vanish.

As far as the irregularities of magnetic lines are concerned, generally these can of course only be shown on maps drawn on a very large scale. Such detailed magnetic maps are still very rare, and consequently very little is known about these irregularities. Magnetic maps on a very small scale, showing for instance the whole surface of the earth do not allow the representation of the special irregularities. Such general maps are a kind of illustration to the theory of Gauss, according to which the magnetic phenomena observed on the surface of the globe are functions of Latitude and Longitude.

The causes of the smaller irregularities consist in conditions of the superficial parts of the earth. The shape of the surface may have some influence, and we may perhaps expect greater complications in the details of magnetic curves where the differences of level are so considerable as on and near Japan.

Lamont's magnetic maps of Bavaria and Southern Germany show the declination lines in intervals from 10′ to 10′.

Some irregularities may be noticed on these maps. The distance of two declination curves is on an average about 4 German miles; West of Karlsruhe, however, the 1° 40′ and the 2° curve are only 1 mile from each other and near Darmstadt the distance amounts to 8 miles. A similar irregularity may be noticed between Bamberg and Bayreuth, and a still more considerable one in the neighbourhood of Salzburg.

The Bay of Finland gives a further example of exceptional directions of the needle. The irregular distribution of magnetism in this part has been investigated by R. Lenz. He found the irregularity to be greatest on the Island of Stenland. At Junnersö he found not less than 9 poles. It is highly probable that this peculiar irregularity may be caused by masses of iron ore found here at a number of points. These examples prove the existence of irregularities in other parts of the world.

I do not attribute much value to the details of the curves for Ino's time and I have said so in my paper, but I cannot agree with Mr. Knipping if he maintains an error of 0.5 to 0.7° would be sufficient to change the irregular zero curve into a regular one. This change would require a very peculiar and very improbable distribution of the errors. An inspection of the original map will convince Mr. Knipping that the greater number of the data by which the curves were determined are *of course* not on but between the curves. In constructing the map I have endeavoured to draw the curves in exact accordance with the material, however insufficient it may be, I had at my disposal. If two persons (to use Mr. Knipping's example, but not to the same effect), working according to this principle of mine, draw curves, quite independently from each other, but employing the same data, their representations will become nearly the same; but if they do not work according to the same principle, if f. i. one rejects all those observations which make the curves irregular, then one will get a more complicated, the other a less complicated system.

For the construction of the curves relating to Ino's time I made use of about 50 compass measurements. These were taken during the last year on my travels through Northern

Japan. It must be remarked that my notes apply only to North Japan and that the curves for the present time were put in for comparison.

With regard to Mr. Knipping's final remarks I may be allowed to repeat what I stated in my paper, namely, that my notes are only intented to be an introduction to future studies and investigations, and that I long for the time when it will be possible to publish the magnetic materials to be collected by the geological Survey in a far more complete and definite state than those scanty notes which I took the liberty to bring before this society.

Mr. Knipping replied:—

If Dr. Naumann himself also places little value on the sinuosities of his lines of equal variation, then there was all the more reason to suppress them as much as possible in a *rough sketch*, as those mentioned by me are improbable on the face of them; and a sinuosity, amounting to an acute angle in one line, disappearing entirely in the next one, distant from the first about 100 miles and on the whole parallel to it, can certainly not be called a *small* one, it is rather an *unusually large* one.

That the line near Sado was drawn with the help of values partly determined on shore, of which I am well aware, does not prove anything in favor of this angle, as long as the probable error is not at least roughly given.

The examples adduced from the magnetic survey of Bavaria and Southern Germany, as well as the one in the bay of Finnland, cannot be compared with the irregularities mentioned by me, because they are different in kind. In the first case *varying distances* in a system of isogones, running about *parallel* to each other, have nothing in common with our case, where *the angles or bends* in *one* line, do not appear at all in the *next* one. Secondly, in the Gulf of Finland, the great irregularities are *lasting;* they were observed in 1750, in 1860, and will be there to-day; while the disturbance for Ino's time, marked near Morioka, according to Dr. Naumann's own sketch, has *disappeared entirely.*

The method employed for drawing curves exactly according to the values found must lead to unsatisfactory results, if the probable error is large in comparison with the quantities determined, as is the case in all three instances which I mentioned.

To Mr. Knipping's renewed objections, Dr. Naumann further replied:—

1. The map accompanying the paper has been designated by myself: "a mere illustration to the notes." Having said in these notes: "the curves follow a crooked line and their course appears to conform to certain lines peculiar to the configuration of the Japanese Islands," it may be easily decided whether it would have been reasonable or not to "suppress" the sinuations. Even a rough sketch of a crooked line cannot look regular. I should consider it a quite unusual method in physical science to reject observations or results at once because they appear "improbable on the face of them." When I was speaking of "the smaller sinuations" I wanted to announce that there are smaller and larger sinuations in the map; the word small can therefore not be taken in an absolute but only in a relative sense.

2. The probable error of a number of values used for the construction of the Sado sinuation does not require special quotation, as it can be determined quite independently from my notes. I have said a number of values found by magnetometer measurement were used. It is generally known to what degree of correctness the declination must be determined with a magnetic theodolite. The maximum of the amplitude of daily oscillation is likewise known. It may be stated however that even an error of 10′ to either side would not be sufficient to make that irregularity which I called the Sado-sinuation disappear.

3. I have not said that the magnetic irregularities in Germany and in the Gulf of Finland ought to be compared with those in Japan. Though detailed magnetic maps are very scarce — those which are known show the existence of irregularities, this is what I pointed out. If it be admitted that the magnetic curves are subject to irregularities in their course,

it may be expected that these irregularities will be found of a different character and of different extent in different parts of the world.

4. The probable error is not large in all cases, but it is very small in a number of cases. Altogether the map in question does not pretend, standing by itself, to offer final results; it is much more intended to be an inducement to future observations, by which alone the distribution of magnetism in Japan can be shown in an accurate and definite way.