A Brief Account of the Life and Work of

Tadataka Ino.

By

Ryokichi Otani.

[For some years past, the Imperial Academy has been collecting materials for compiling the work on the illustrious surveyor Tadataka Ino (1743-1818). The task was imposed on Mr. R. Otani under my supervision. A lapse of a century since the survey has effaced most of the precious relics of this memorable work. It was only by following some tattered fragments of his writings that a portion of his methods of surveying was made clear. By a lucky chance, however, his diaries stating the minute proceedings of his survey were perfectly preserved, so that the motives which led to the survey were brought to light, and his progress could be traced from day to day during the entire course of the survey, which lasted for about 16 years. From these documents, we found that his survey was in fact in the nature of a coast survey. The original idea of undertaking so stupendous a work and of bringing it to completion was due to Sakuzaemon Takahashi, and the instrumental difficulties were overcome through the able direction of Gorobei Hazama. A prominent place among Japanese scientists of the 18th century has, however, to be accorded to Goryu Asada, who gave a great impetus to astronomical theories and observations, educated the two eminent men above mentioned, and at last gave rise to the memorable survey. The final development in actual measurements must be ascribed to Ino, whose name is well-known among the Japanese. An account of his life and work was published in a quarto volume (xxxv + 766 Pl. 10) in March 1917, written in Japanese.

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The following is a brief account in English of the great scientific work, which was accomplished at a period when the only foreign influence present had come through Dutch traders. It is hoped that the mist which still obscures knowledge of the scientific originality of the Japanese, before intercourse with different European nations was effected, will to a great extent be cleared away by the evidence contained in the following pages.—Hantaro NAGAOKA.]

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I. The Life of Tadataka Ino.

The Earliest Days.

The illustrious Japanese surveyor Tadataka Ino, whose work will be sketched in the following pages, was born on Feb. 11, 1745 (Gregorian Calendar). His father Sadatsune Jinbo, the third son of a village officer of Onzumimura in the Province of Kazusa, was adopted by Gorozaemon Ozeki in Ozekimura in the above mentioned province, and married his daughter, by whom he had three children, the last of them being the future surveyor.

In his boyhood, the surveyor was known by the name Sanziro, a name which in later life recalled years of poverty. In his seventh year, he lost his mother, and on account of this bereavement his father was obliged to return to the original family. Sanziro, however, did not follow his father, and remained in the Ozeki family until he was eleven years old. It is said of him that during this interval he was employed as a watch boy of fishing materials on the shore of Kujukuri, no time being allowed him to learn even a primary course of reading and arithmetic. Relieved from this occupation, which was little better than that of a watch-dog, he returned to his father's house, but had to taste the bitterness of poverty and of maternal bereavement. During the wandering life that he led among other people, including his relatives, he had various chances of learning the Chinese classics and dipping into the secrets of mathematics and of medicine.
Although not much is known of his life during this miserable period, the tide of fortune turned, and he had the felicity of entering the family of Ino, and with assiduous efforts laid the foundation of the enduring prosperity, which was the key to his career and renown.

His Life as Chief of the Ino Family.

The genealogy of the Ino family can be traced to upwards of a thousand years. This old and opulent family flourished for several centuries at Sawaramura in the Province of Shimosa, till it reached Nagayoshi Ino, who died in 1742, leaving a wife and a little daughter. The mismanagement of domestic affairs by the relatives gradually led to the decline of fortune some twenty years after this unhappy event. What was still more unfortunate was the death of the young husband of the heiress, two years after their marriage. These circumstances necessitated the selecting of a second husband, with sufficient ability to restore the fallen state of the Ino family to its former prosperity.

Although Sanjiro's social position was lower than that of Ino's, Suyetada Hirayama, an elder brother of the widow and second cousin of Sanziro, was bold enough to propose Sanziro as a candidate, as his acute eyes perceived the signs of future success in the hands of the talented youth. The proposal met with the approval of the family relations; to bring the social position of Sanziro to an equality with that of Ino's, he was adopted into the Ino family as son-in-law of Hirayama, and the marriage ceremony took place on January 21, 1763. Thenceforth, Sanziro Jinbo was called by the new name Saburoyemon Tadataka Ino, Saburoemon being the common name and Tadataka the real name. The former is brought down even to this day, and the successor of the great surveyor retains at present the name once borne by his illustrious predecessor. The latter was chosen by

(1) 佐原村  (2) 下総  (3) 伊能長柄  (4) 平山季忠  (5) 伊能三郎右衛門忠敬

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Nobukoto Hayashi, President of the University for Chinese classics in Yedo, who admitted him as a nominal private pupil. It is much to be regretted that the true pronunciation of his name has been so often mistaken that his real name became usually Tadayoshi or Chukei.

From this time onwards, his mind was concentrated on the task entrusted to him; he made many strenuous efforts to restore the fading prosperity of the family to its former blooming state. Maintaining strict economy in the household, and extending the family calling of 'sake' brewing to grain and fuel trades, he succeeded in every way in accumulating wealth, so that in the course of a dozen years, he had gathered sufficient money to restore the family estate to its former level. Thus, his first desire being satisfied, he could devote his leisure hours to the study of Japanese and Chinese classics and to the supervision of the village affairs.

In 1778, the village of Sawara, which had formerly been under he direct sway of the Shogunate, was transferred to the domain of Hyuganokami Tsuda, who, acknowledging the business talent of Ino, appointed him in 1781 as the head village officer of Sawara. Following the great eruption of Asama in 1783, the Kwanto region was devastated by a terrible flood in 1786, which spread horrible famine over the inundated districts. To mitigate the calamities in his village, Ino did his utmost, by distributing grains to the starving people from his own granaries, and by providing the sick with medicine. By this benevolent action, the village of Sawara remained unscathed by the evils of famine, and Ino was amply rewarded for his praiseworthy conduct by the lord of the land.

On the approach of his fiftieth year, Ino was absorbed with the study of astronomy, and amused himself with the compilation of almanacs. His knowledge of the astronomical science was, however, mostly derived from a Chinese calendar theory, Shou-
shih-li-fa. But as he could not get enough information to compute the position of the heavenly bodies accurately, he was confronted with numerous difficulties and doubts, which he believed could only be cleared up by studying the science in a proper manner.

At that time, his eldest son was so grown up that he could leave to him the domestic affairs and the trade of the family, and it was with the purpose of following amateur science more closely that he transferred the family business to his son and retired at the beginning of 1795. According to the prevalent Japanese custom, his son succeeded to the name of Saburoyemon, while Ino assumed the new name Kageyu. It was in the summer of 1795 that he settled at Kuroyecho, Fukagawa, in Yedo, and devoted himself entirely to the study of astronomy.

Iuo as Pupil of Yoshitoki Takahashi.

The exact details of the calendar used by the Japanese before the end of the 7th century are obscure. In 692, the calendar was compiled after the Chinese method, which after several alterations came down to the year 862, when it was superseded by the Hsüan-ming-li-fa, a method introduced by Hsüang of the Tang dynasty. For more than eight hundred years, the calendar was compiled according to this system, but on account of its inaccuracy the true date for the Vernal Equinox differed from that calculated by nearly two days. At last Sukezayemon Shunkai Shibukawa introduced a new system called the Jokyo-rekiho, in 1685, and substituted it for the system used for so many centuries. Based on the Shon-shih-li-fa, a Chinese method compiled by Kuo-shou-ching of the Yuan dynasty, Shibukawa was so keen-sighted as to alter some of the methods of reduction and to introduce those constants befitting to our land, which were mostly the fruits of long continued observations by Shibukawa.
himself. In fact, we do not hesitate to assert that ever since that time our calendar system has been on the right track.

In spite of the improvement thus introduced, it was still unfit for use for a long period, so that in the course of many decades, error accumulated to an appreciable amount. The governing Shogun1 Yoshimune Tokugawa2 was a patron of astronomical science; he appointed Seikyu Nishikawa,3 who was a son of Joken Nishikawa,4 an official interpreter at Nagasaki5 and celebrated for his knowledge of astronomy as cultivated in Europe, as the chief astronomer of the Shogunate Observatory, with the object of reforming the calendar on the basis of occidental science. The proposal was, however, frustrated by the death of the Shogun, as well as by Nishikawa's imperfect knowledge of the subject. The calendar reform was at length carried out in 1754, chiefly by the hand of Yasukuni Tsuchimikado,6 who was an astronomer of the Imperial Court and enjoyed a different opinion from that of Nishikawa. For this purpose, some simple and rude instruments of European style were used for observation and the trigonometrical table was utilized for calculation. The new calendar was, however, very unsatisfactory, presenting no special improvement in theory other than some alterations of minor importance, so that it failed to predict a solar eclipse which occurred within ten years of the reform. This deficiency was filled in by a temporary adjustment, but the fundamental revision of calendar calculation became a matter of urgent necessity. Toward the close of the 18th Century, the Shogunate astronomers were appealed to to reconstruct a calendar system, introducing Kepler’s theory of planetary motion, which was made known to our countrymen through the Supplementary Treatise of the Li-hsiang-k’ao-ch’eng,7 compiled by J. Kögler and A. Pereyra, Jesuit missionaries in China. This proposal, however, was temporarily defeated on

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(1) 役軍 (2) 徳川吉宗 (3) 西川正休 (4) 西川如見 (5) 長崎 (6) 土御門泰邦
(7) 暦象考成街編

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account of the imperfect knowledge of western science on the part of the Shogunate astronomers, none of whom was sufficiently skilled to accomplish the work imposed on them.

Fortunate for science was the part played by Yasuaki Asada\(^1\) in Osaka\(^2\) in completing the calendar reform. He was a physician by profession, but being especially fond of astronomy, studied it with such assiduity that he devoted much of his time to observations and to the investigation of European theory. Prominent among his pupils were Sakuzayemon Yoshitoki Takahashi\(^3\) and Gorobei Shigetomi Hazama\(^4\); the former was thoroughly versed in Kepler's theory of planetary motion, while the latter made the construction of accurate instruments his speciality. The Shogunate Government, recognizing the inability of the astronomers under it to effect calendar reform, was wise enough to call Asada for the purpose, but he declined the call by reason of a motive which much exalted his unblemished character. The reason for it cannot be treated within so short a space as the present exposition. Instead of going himself to Yedo to assume the high office offered to him, he gave the necessary instructions to Takahashi and Hazama and sent them to execute the proposed reform of the calendar. Accidentally, it was in the same year, 1795, when Ino settled himself in Yedo, that the two distinguished pupils of Asada made their entrance to the seat of the Shogunate Government. A fine opportunity was thus offered for bringing these personages together to interchange views as regards astronomy and geodesy.

The astronomy cultivated in Europe was only dimly understood by Ino at that time, but on consulting Takahashi, he recognized at once the superiority of western science, so that in spite of his declining years he resolved to study it under Takahashi. Ino was then fifty years old and nineteen years the senior of Takahashi. This difference of age was no impediment to the attachment between pupil and teacher, which was so close that

\(^{(1)}\) 麻田安彰 \(^{(2)}\) 大阪 \(^{(3)}\) 高橋作左衛門至時 \(^{(4)}\) 間五郎兵衛重富
even death could not sever it, as will be explained later. The toil and perseverance with which under the guidance of Takahashi, he followed the theory and practised the observations, matched the assiduity of young aspirants to astronomy. The observing instruments were constructed under the direction of Hazama and set up at his residence in Kuroyecho. His progress in assimilating the astronomical knowledge imparted to him by Takahashi was indeed astonishing, and Ino was so noted for his skill in observation and numerical calculation that his comrades nicknamed him "Suiho-sensei," which signifies 'master of computation.' In the course of a few years, he was imbued with such astronomical knowledge that he could aspire to cultivate a new field of research, as his restless mind was ever prepared to enter the path of glory that would make his name immortal.

The work of calendar reform, with which Takahashi and Hazama were mostly occupied, was completed in 1797 with numerous improvements; to the great regret of the compilers, however, the accurate prediction of solar eclipse for principal towns in Japan was rendered extremely difficult, as their positions as well as the dimensions of the earth were but imperfectly known. The ardent desire of measuring the dimensions of the earth awakened in Ino the hope of arriving at the result, by measuring the distance and latitude difference between the Astronomical Observatory and his residence, which were but a few kilometers apart from each other. On consulting his teacher, Ino was informed of the futility of the proposal, as the stations were not far enough, but was told that probably a regular survey along some long route on a high-way connecting Yedo with Yezo\(^{(2)}\) would lead to accurate determination of the desired dimensions.

Towards the end of the 18th Century, the Shogunate Government was busy with the cultivation of Ezo and the coast defense of the island, to protect it from the incursion of the Russians, who not long before had encroached on the Kurile Islands.\(^{(1)}\) For

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\(^{(1)}\) 推步先生  
\(^{(2)}\) 蝦夷
this purpose, it became absolutely necessary for the Shogunate officers to be thoroughly conversant with the geography of the island, for which the possession of accurate maps was the first requisite. As a rough sketch of the region existed at that time, Takahashi seized this fine opportunity of carrying into effect Ino's project of measuring the dimensions of the earth, while at the same time fulfilling the urgent need of the Shogunate officers by surveying the coast of Ezo. Takahashi persuaded the Government to send Ino to Ezo with the above object, and at length obtained the assent that Ino might conduct the work of surveying with his own instruments and at his own expense.

Ino's Work in Land Surveying.

It was in July of 1800, when permission was given to Ino to carry out his plan. But, as the ability of Ino in land surveying was quite unknown to the officers of the Government, and moreover, as the surveyors previous to him had all failed to bring the expected results, it was natural that the officers should hesitate to treat him favourably. They issued only an instruction to village officers to give him certain conveniences when he should pass by, and gave him a small sum of money as salary, treating him as a 'ronin' or lordless 'samurai.' Under such circumstances, it was impossible for Ino to transport all of his large and accurate instruments, so that he decided ultimately to carry with him, besides small instruments, only an astronomical quadrant and a large magnetic theodolite, which were indispensable for his work.

On the morning of June 11, 1800, Ino, who was then in his fifty-sixth year, made his first step toward the work of land surveying from his residence at Kuroyecho, accompanied by his second son Takayoshi Ino, two pupils and two servants. He proceeded along the Oshu Highway towards the north at a speed of 30–50 km. per day, measuring the length of the route by the number of footsteps, and the direction with a small magnetic compass, and determining by astronomical observations the...
latitude of every town or village where he passed the night. After about 20 days, he arrived at Mimumaya, a small town in the north end of Honshu, whence he sailed to the Island of Ezo.

At that time, Ezo was in such a primitive state of civilization that it was inhabited only by a small number of natives and officers, and travellers might find their shelter only in cottages built officially at a distance of 20–30 km. from each other along a few principal but exceedingly poor roads. Owing to the want of carriers, Ino was obliged to leave the large magnetic theodolite at Hakodate. At first, he intended to survey the roads in Ezo with the measuring rope, but seeing that it required too much time, he gave up this plan and continued his work in the same manner as that which he had employed on the Oshu Highway. In case the weather was unfavorable, however, he stayed in a cottage long enough to execute the necessary astronomical observations. Having spent more than sixty days for the survey of the road connecting Hakodate and Nishibetsu, chiefly along the south-eastern coast line, he reached the latter town which is not very far from the east end of the Island. He wished to proceed farther, but the lack of carriers hindered him, and he turned back to Hakodate, taking the same road as before and repeating the measurement. From Hakodate he continued his journey westward to Matsumaye, whence he sailed back to Mimumaya. The Oshu Highway was measured again on his way home, and on Dec. 7 he returned to Yedo.

Combining the materials obtained in this survey, Ino found the length of meridian arc to be about 27 ri (nearly 106 km.) per degree, though it was not accurate enough, owing to the roughness of measurement. Adopting this provisional value of the meridian arc, he constructed the maps of the surveyed region in two different scales of 1:43636 and 1:436364, and in Feb. 1801 they were presented to the Shogunate officers who received them.
with satisfaction, recognizing the ingenuity of Ino in the art of surveying.

Thereupon Ino proposed to continue his work, in order to perfect a coast map extending from Yedo to Ezo, surveying more accurately the whole coast line of Ezo and the east coast of Honshu under more favourable conditions and with the assistance and protection of the Government. But this proposal was not accepted, as actual conditions made it impossible to give him more assistance, and after some negotiations, in April 1801 he obtained permission to survey the east coast of Honshu. This survey was to be made under the same conditions as those of the previous year, leaving the Island of Ezo unfinished.

At that time, it happened that the public-spirited conduct of Ino at Sawara many years before was made known to the Shogunate Government, and as a result he and his elder son were rewarded with a small sum of silver and with a right belonging to the ‘samurai’ class, that is, to call the family name publicly and to wear a pair of swords. This fact gave him no small advantage in the work of surveying, as his name became known widely, his noble character being certified by it.

On May 14, he set out on his journey, taking his second son, three pupils and a servant as his companions. At first, he measured in about sixty days the coast of the Provinces of Musashi, Sagami and Idzu as well as the eastern part of the Tokai Highway. Then Awa, Hidachi and Mutsu, and having spent more than 130 days he arrived at Mimunaya. On his way home he measured the Oshu Highway once more, and on Jan. 10, 1802, he returned to Yedo.

The official protection given to Ino during the present excursion was apparently the same as that in the preceding, but as the state of things in Honshu differed very much from that in Ezo, he could carry on his work under far more favourable conditions,
thus greatly improving the accuracy of measurement. The whole coast line was measured with ropes at the rate of 8–20 km. per day, the measurement being, in most cases, conducted by two parties. The greater part of the highways, however, was measured by means of a measuring wheel, while in the northern part of Honshu, where its use was hindered by snow, the length of the road was determined simply by the number of footsteps. Reducing and adjusting the materials obtained by those measurements, he arrived at the result that the mean length of meridian arc is 28.2 ri (110.8 km.) per degree, and in April 1802 he presented to the Government the maps drawn in three different scales of 1:36000, 1:216000 and 1:432000.

The sum of money hitherto allowed to Ino as salary amounted to about 60 ryo¹ (1 ryo of that time is nearly equivalent to £1.2) only, while the total expense was beyond 200 ryo, whence it is clear that the first two years' work was carried out chiefly at his own expense, as he had proposed to the Government at the very beginning. Now, the above maps, in which the configuration of the eastern coast of Honshu was clearly shown, were much valued by the Shogunate officers, and at the suggestion of Takahashi they ordered Ino, in July 1802, to survey the coast line of provinces lying east of Echizen² and Owari,³ and to complete the map of the eastern half of Japan, giving him substantial assistance, such as a sum of money sufficient to compensate the real expense, and a right to employ a limited number of carriers at state expense.

Hereupon, Ino decided to carry out work with the utmost accuracy, and to verify the length of the meridian arc obtained from the data of the last year, of which his tutor Takahashi had a certain doubt. He set out on his journey on July 10 with his second son and five attendants. He proceeded

¹ 六 ² 越前 ³ 尾張

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along the Oshu Highway to Shirakawa,\(^1\) and then turning to the Dewa Highway\(^2\) he arrived at a small harbour called Noshiro\(^3\) where he tried to observe a solar eclipse, but in vain owing to bad weather. Having continued his work along the highway to Aomori,\(^4\) he surveyed the coast line of the Provinces of Mutsu and Dewa\(^5\) bounding the Sea of Japan, and came down to Naoetsu.\(^6\) From this place, he made his way home, measuring the Echizen Highway\(^7\) and a part of the Nakasen Highway,\(^8\) and on Nov. 18 he reached Yedo.

In this year, the lengths of roads and coast lines were measured with iron chains or rattan ropes which were frequently standardized, and the measuring wheel was used only for check and for the measurement of short branch routes. The directions of routes were carefully measured in duplicate with two magnetic compasses, and their inclinations, which in foregoing years had been simple eye estimates, were determined by means of a small quadrant. Calculating again the value of the meridian arc from new materials obtained in this year, Ino was very much pleased to get exactly the same result as before.

After finishing the first draft of the map, he set out again on his journey on April 16, 1903, and surveyed in succession the Tokai Highway westward to Numadzu,\(^9\) the coast line of the Provinces of Suruga,\(^10\) Totomi,\(^11\) Mikawa\(^12\) and Owari, the highway connecting Owari and Echizen, the coast line of the Provinces of Echizen, Kaga,\(^13\) Noto,\(^14\) Etchu\(^15\) and Echigo,\(^16\) and the Island of Sado.\(^17\) Thus, having completed the survey of the coast line of the eastern half of Honshu, he made his way home, measuring a highway on the way, and reached Yedo on Nov. 20. The method of measurement adopted in this course was essentially the same as that employed in the previous year, except that a theodolite of semicircular form was introduced and put into actual use.
Before the completion of Ino's map of the eastern half of Japan, which map in the course of construction combined all the materials of measurement obtained since 1800, Takahashi died, on Feb. 15, 1804. As already explained, the relation of Ino to Takahashi was not simply that of a pupil to a teacher; Takahashi was an adviser to all of Ino's scientific work. He not only supplied Ino with new information, but took the trouble of recommending Ino to the Government that he might gradually extend the work of survey. In 1803, a Dutch translation of Lalande's Astronomia came to the hand of Takahashi, and he perused it with great assiduity. But, it was no easy task to understand a European language at that time, and as his bad health was unable to bear the heavy strain of official duties and the digestion of the valuable store house of astronomical information, he succumbed in his forty-first year. He left various posthumous works and many projects unexecuted, but it was a consolation that he had the satisfaction of learning the dimensions of the earth by Ino's measurements, which agreed tolerably well with the result obtained in Europe as recorded in the Astronomia.

The maps of the eastern half of Japan were completed in the summer of 1804 and were presented to the Government. They were drawn in three different scales: the largest was in the scale of 1:36000 and consisted of 69 sheets, excepting the Island of Ezo, and the middle in the scale of 1:216000 consisting of 3 sheets, excepting the Island of Ezo, and the middle in the scale of 1:216000, consisting of 3 sheets, while the smallest was in the scale of 1:432000, consisting of 1 sheet with the preface written by Sakuzayemon Kageyasu Takahashi, the eldest son and successor of Yoshitoki Takahashi, and with the introductory note written by Ino. In these maps, the configuration of the coast line and the topographical feature of the land, of which the Shogunate officers knew hitherto very little, were represented clearly and minutely, so that they were again astonished at Ino's
ability. Thereupon they appointed Ino to a Shogunate officer of low rank called the Kobushin-gumi, giving him ‘10 nin buchi’ or an annual ration amounting to 18 koku (=3250 litre) in rice, and ordered him to become an assistant of the Shogunate Astronomer Kageyasu Takahashi.

In Jan. 1805, Ino was ordered to survey the western half of Japan as a piece of purely official work; all possible conveniences were given to him for carrying out the work effectually, and an instruction was issued for the Feudal Lords in the western region to assist the work. He formed a survey party, consisting of Zensuke Takahashi (lately called Sukezayemon Kagesuke Shibukawa), who was the second son of Yoshitoki Takahashi, two subordinate officers of the Astronomical Observatory, his second son, four pupils, and six attendants.

He set out on his journey on March 25, and began the work from the gate called the Okido at Takanawa in Yedo. Having carried on accurate measurements along the Tokai Highway, he proceeded along the coast line of the Provinces of Ise, Shima, Kii and Idzumi, and arrived at Osaka. He turned towards Kyoto and Otsu to survey the margin of Lake Biwa, and then he continued along the coast line of the Provinces of Settsu, Harima, Bizen, Bitchu, Bingo, Aki, Suwo and Nagato which face the Inland Sea, Seto and along the coast line of the Provinces of Iwami, Idzumo, Inaba, Tajima, Tango and Wakasa facing the Sea of Japan. On the way, innumerable islets studding the Inland Sea and the Island of Oki in the Sea of Japan were also surveyed.

At first, Ino had made an arrangement to complete the survey of the whole western half of Japan in a continuous journey of
33 months. But, owing to the complicated configuration of the coast line of Kii Peninsula, his arrival at Osaka was already delayed by three months, and though he surveyed the coast of the Inland Sea by means of three or four small parties, the delay became gradually prolonged, as the islets were far more numerous than he thought them to be. Moreover, he fell ill which kept him out of action for 15 weeks. On this account, he changed his initial plan and determined to carry out the work in sections, returning to Yedo at the end of every excursion. Thus, from Tsuruga, he made his way home, measuring a few highways and reaching Yedo on Dec. 24, 1806.

The method of measurements adopted during this journey was nearly the same as that in the previous survey. But according to the experiences of foregoing years, the use of the measuring wheel was discontinued, while the observation of the eclipse of Jupiter's satellites was introduced in its place as a means of determining the longitude.

After he had busied himself in drawing the maps and in conducting the fundamental astronomical observations at his residence with his collaborators, he set out for the Island of Shikoku on Feb. 21, 1808, leading a party which consisted of 16 persons. On the way a few highways were measured, and then the Island of Shikoku and the Island of Awaji were surveyed in about 9 months. On the way home, he measured a highway which connects Osaka and Tsu, and returned to Yedo on March 3, 1809.

In September of the same year, the maps of the region of Shikoku as well as a map of all Japan were presented to the Government, the latter being drawn provisionally to comply with the earnest requirement of the Government, in the scale of 1:864000, using partly the rough materials obtained from various books and maps. On Oct. 6 of the same year, Ino set out for the Island of Kyushu accompanying 16 persons, and on
the way he measured the Nakasen Highway and the Sanyo Highway.\(^1\) Arriving at Kokura,\(^2\) a town on the north end of Kyushu, he began the survey of the coast line of the Island, proceeding in clockwise direction. Having finished the survey of the coast of the Provinces of Buzen,\(^3\) Bungo,\(^4\) Hyuga,\(^5\) Osumi,\(^6\) Satsuma\(^7\) and Higo\(^8\) including the Islands of Amakusa,\(^9\) he proceeded from Kumamoto\(^10\) towards Oita\(^11\) crossing the Island, and then continued his work towards Kokura. From Kokura he made his way home, and on his way he surveyed a number of highways in the region of Chugoku.\(^12\) Among others; a highway connecting Okazaki\(^13\) and Kofu,\(^14\) and the Koshu Highway\(^15\) which connects Kofu and Yedo were also measured on this occasion; and on June 28, 1811 he returned to Yedo.

During this excursion, the method of measurement was quite the same as on the previous occasion, but Ino tried his utmost to observe the eclipses of Jupiter’s satellites; in addition to that he endeavoured to measure as many highways as possible, and in order to increase the efficiency of the work the direction of the branch party was left to Teibe Sakabe,\(^16\) a subordinate officer, who acted independently of the main party, meeting at intervals of a week or more, to consult on the general plan of surveying.

The maps of the region surveyed in this excursion were finished at the end of 1811, and on Jan. 9, 1812, Ino set out again for Kyushu to survey its remaining part, accompanied by 18 persons. He proceeded towards Kagoshima,\(^17\) measuring on the way a number of highways, and then sailed to the Islands of Tane\(^18\) and Yaku.\(^19\) Having finished the survey of these Islands, he carried on his work along the principal roads in the main part of Kyushu, and along the coast of the Provinces of Chikuzen,\(^20\) Chikugo\(^21\) and Hizen.\(^22\) He then sailed to the Islands of Iki\(^23\) and Tsushima,\(^24\) and to the Archipelago of Goto,\(^25\) where the work of

\(^{1}\) 山陽街道 (2) 小倉 (3) 陸前 (4) 陸後 (5) 日向 (6) 大隅 (7) 播磨 (8) 肥後 (9) 天草 (10) 熊本 (11) 大分 (12) 中國 (13) 島崎 (14) 甲府 (15) 甲州街道 (16) 坂部負兵衛 (17) 鹿児島 (18) 種子島 (19) 霧島 (20) 筑前 (21) 筑後 (22) 肥前 (23) 壱岐 (24) 對馬 (25) 五島
surveying was successfully carried on, in spite of topographical difficulties. But in September of 1813 an unhappy event occurred at Goto. Teibei Sakabe, who had been Ino's chief assistant since 1805, died thereof fever. The survey of Kyushu, however, was completed in a few months after the death of Sakabe, and Ino made his way home towards Yedo. On the way, various highways in the region of Chugoku, Kinai, and Tosando were measured, and he returned to Yedo, on July 9, 1814. Soon after his arrival at Yedo, he moved to Kamejimacho near Nihonbashi, as his former residence at Kuroyecho, which had been the standard station of latitude observation, had become too narrow to carry out map making.

In March of 1815, he measured the roads in Yedo which connect Nihon-bashi to each of the entrance gates of the city, as the former was the general initial station from which to reckon the mileage of principal highways. In the same year, an order to survey the Seven-Islands which lie in the Pacific Ocean was given to him. But as he was already over seventy years old and on account of ill health, it was decided that the actual work should be conducted by subordinate officers. A party was composed of 11 persons, a subordinate officer called Jinzayemon NAGAR being the leader. This party left Yedo on June 4, 1815, and the Shimoda Highway, the Seven Islands, the east coast of the Province of Idzu, and numerous roads in the Provinces of Suruga, Sagami and Musashi were surveyed in succession. The work was completed in about a year, and the party returned to Yedo on May 9, 1816.

The maps hitherto presented to the Government, being drawn separately for each district with materials obtained in each excursion, lacked the generality of a plan, so the Government ordered Ino to construct a map of all Japan, combining and adjusting all data which he had obtained by his measurements since 1800.

(1) 諏訪 (2) 東山道 (3) 龜島町 (4) 日本橋 (5) 七島 (6) 永井甚左衛門
(7) 下田街道

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Ino, thereupon, proposed a scheme of surveying the principal roads, lakes and rivers in the eastern part of Japan, which had been left out of consideration in the previous measurements, and of constructing a map having nearly equal degree of accuracy throughout the whole land. This proposal was not adopted, but in the autumn of 1816, he was ordered to survey the city of Yedo with minute details.

The survey of Yedo was accomplished in little more than 10 weeks and its map, drawn in the scale of 1:6000, was presented to the Government in the next year. But the completion of the map of all Japan was much delayed, owing chiefly to the following causes: the examination and the adjustment of the whole materials required far more time than Ino had estimated; three or more of his subordinate officers and pupils were obliged to retire from their services by sickness or by other unavoidable circumstances; and the extent of the map was enlarged to include the whole island of Ezo, utilizing the data obtained by the measurement of Rinzo Mamiya, a pupil of Ino, who was renowned as an explorer of Saghalien and eastern Tartary, and as the discoverer of the Straits of Tartary or the so-called Mamiya-no-seto.

While the work of map-making did not proceed rapidly, the health of Ino declined gradually, and on May 17, 1818 he passed away in his seventy-fourth year in his residence at Kamejimacho. He left a will that he should be buried by his teacher's side, in order to express his cardinal thanks, for his work had been built up by the kind guidance of his teacher, without whose aid he could have done nothing. His wish was realized, for he is buried close by the tomb of Yoshitoki Takahashi, in the grave yard of Genkuji in Asakusa, Yedo. His death was, however, kept secret, as the work of map-making was still in progress at that time.

In the summer of 1821, the maps of all Japan drawn in three different scales, and a volume of books called the Yenkai-jissoku...
roku\(^1\) were completed and presented to the Government. Though these original maps were afterwards reduced to ashes by fire, a duplicate that had been constructed, identical with the original and preserved by Ino's descendants, is transmitted to the present day and is now kept in the library of the Tokyo Imperial University.\(^2\) The largest map drawn in the scale of 1:36000 consists of 214 sheets: on this map, the coast lines and roads are drawn minutely with red lines; the positions and names of villages, temples, rivers, boundaries of provinces and districts, etc., which are situated in the neighbourhood of the measured routes, and those of mountains and islands which were measured by the method of intersection, as well as the distinction of domains with the names of Feudal Lords, are shown in the clearest way. Moreover the general topographical features of coast and land are indicated in different colours according to the sketches made during the excursions. The map of middle size drawn in the scale of 1:216000 consists of 8 sheets; though this map is not so minute in detail as the largest one, the azimuth lines of principal mountains and islands with their numerical values are drawn on the map with red lines, and the meridian line and parallels with black lines, so that it is convenient to get a glimpse into the general configuration of the whole land. The smallest map consists of 3 sheets and is drawn in the scale of 1:432000, omitting some details given in the map of middle size. The Yenkai-jissoku-roku, which consists of 14 books, is a record giving the latitudes of stations where Ino executed his astronomical observations, the distances between principal towns or villages in highways and in coast lines, and the marginal lengths of lakes and islands.

On Sep. 29, 1821, the death of Ino was made known to the public, and few days later the Shogunate Government gave Saburoyemon Tadanori Ino,\(^3\) a grand son of the surveyor '5 nin buchi\(^4\)' or an annual ration amounting to 9 koku (=1620 litre) in rice, and a small piece of ground in the vicinity of Nihonbashi.

\(^{1}\) 海測測量録  \(^{2}\) 東京帝國大學  \(^{3}\) 伊能三郎右衛門忠論  \(^{4}\) 五人扶持
in Yedo, as a reward for the work which his grand father had completed with extraordinary effort through long years.

Effects of Ino’s Maps upon Home and Foreign Affairs.

Ino’s maps were kept secret in the library of the Shogunate Government and were utilized only for official business; nevertheless a serious matter happened: Kageyasu Takahashi gave a copy of the smallest scale map to Philipp Franz von Siebold, a German, who came to Yedo in 1826 as a physician attached to the Dutch Ambassador, in return for books which he received from Siebold. This fact was detected in 1828, and Takahashi was arrested, while Siebold was expelled from our country, all documents and maps which he had collected in Japan having been confiscated by the Government. Takahashi died on March 20, 1829, of disease while an unconvicted prisoner, and after his death it was pronounced that his crime deserved capital punishment.

On the other hand, Siebold returned to Europe with Ino’s map which he had copied secretly, at a critical moment, from the copy given by Takahashi, and sent it to Krusenstern, an eminent Russian hydrographer, in order to have its true value criticized. Krusenstern answered to Siebold with the following words:

“...Ohne mich eine genaue Analyse derselben einzulassen, will ich hier nur bemerken, dass nach einer Vergleichung mit unseren europäischen Karten, d. h. mit solchen, welche nach einer genauen Untersuchung von bekannten Seefahrern konstruirt sind, ich nicht anders als sehr günstiges Urteil über sie fallen kann. Nicht nur die Konfiguration der Küsten und das Detail derselben, wo solches auf unseren Karten zu finden ist, sondern auch die Längen und Breiten stimmen auf eine wundervolle Weise und liefern einen interessanten Beweis von den Fortschritten welche die Japaner in der Astronomie gemacht haben......Bei dieser ausserordentlichen Genauigkeit, welche sich fast überall zeigt, wo ein Vergleich mit europäischen Seefahrern zulässig ist, lässt sich wohl mit Gewissheit annehmen, dass auch diejenigen Küsten, welche bis jetzt
nicht haben von europäischen Seefahrern untersucht werden können, den nämlichen Grad der Genauigkeit gewählen, und dass folglich die Lücken, deren es bis jetzt noch viele an jener Küsten giebt, durch Ihre Karten genügend ausgefüllt werden können, bis endlich ein wissenschaftlicher Seefahren dort das Werk vollendet, wozu dem Anscheine nach jetzt keine Aussicht ist......."

In 1840, Siebold published Ino's map, contracting it and changing the original system of projection to Mercator's, without mentioning the name of the illustrious surveyor. Thus, Ino's map was introduced to the libraries of European scholars earlier than those of the Japanese, and several maps of Japan henceforth published in Europe were all based upon this one.

In 1861, the British Navy solicited the Shogunate Government for permission to survey the coast of Japan. Though the Government was very anxious to grant the request, they feared that such work as a coast survey might provoke unexpected complications between nations, owing to the misunderstanding of our people, who were filled with a desire to expel foreigners. It was, however, impossible to reject the proposal, and a British cruiser began the work of surveying. It so happened, however, that the captain of the surveying vessel had an opportunity to see a copy of Ino’s smallest scale map which the Shogunate officer on board had brought for his own use. Comparing the result of new measurements with Ino’s map, the captain found that there was no necessity to remeasure the coast line, and he gave up the work, excepting the sounding of a few ports in the region of Tokaido and the determination of the position of reefs near the Pacific coast. Hence, on the chart of the Japanese coast which was published shortly afterward by the British Admiralty, it was remarked that the coast line had been based chiefly upon the original survey of the Shogunate Government, that is of Ino. A copy of Ino's map which the Government gave to the British on

(1) 東海道

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the occasion of the coast survey is still kept in the library of the British Admiralty.

Ino's maps were also of great efficacy in domestic affairs, giving considerable convenience to the Japanese people: when in the last period of the Shogunate Government, our navy was newly established, these maps served as sole guide for coastal navigation, the map of smallest scale having been published for such use. When, in the early period of Meiji,1) the Imperial Government compiled a new map of Japan, Ino's maps were still taken as its fundamental material.

The merit of this illustrious surveyor was recognized by the late Emperor of Japan, and in 1883, the rank of Shoshi-i;2) or Senior 4th Class was conferred on him.

II. The Japanese Knowledge of Surveying at the End of the Eighteenth Century.

A Short History of the Development of the Art of Surveying in Japan.

Of the knowledge of surveying possessed by the ancient Japanese little is known. But there is no doubt that a certain method of surveying had been introduced from China as early as the 7th century; for, in the Daiho-ryo,3) or an ordinance issued in the 2nd year of Daiho4) (702), the name of the Hai-tao-suan-shu,5) a Chinese book in which some methods of determining the distance and height of a mountain or island are described, is cited as one of the text books on mathematics. The facts that many of the roads running through the plains of the Provinces of Yamato6) and others, which may be considered as ancient remains constructed according to certain rules, are very regular in their distances and directions, and that the streets in Heijokyo,7) or

1) 明治
2) 正四位
3) 大寶令
4) 大寶
5) 海島算術
6) 大和
7) 平城京

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Capital Nara, built at the beginning of the 8th century, and in Heian-kyo, or Capital Kyoto, established at the end of the same century, were constructed according to an exceedingly regular system, prove also that the art of surveying was in practical use in such remote times. Nevertheless, it was gradually discarded during the middle ages as the result of uninterrupted internal commotions, till in the 16th century the intercourse with the Europeans opened a new path to adopting western arts in our country.

According to a manuscript concerning the art of surveying, the European method was transmitted for the first time to a Japanese called Gonyemon Higuchi who lived at Nagasaki, by a Dutchman named Casper in a certain year of Kwan-yei (1624–1643); and it is told that Higuchi spent seven years in obtaining permission to learn that art. Higuchi then taught the art to his pupils Teicho Shimatani, Unsetsu Hirai, Kyuya Yamasaki, Gyobuzayemon Kanazawa and others, but soon after the chief officer of the Shogunate Government forbade the making of the European method public, and henceforth it was transmitted from one to another secretly. Some years later, however, this hindrance was removed and there appeared a surveyor called Taroyemon Teitoku Shimizu, the founder of the Shimizu school of surveying. Shimizu received some instruction on the method of surveying from Kanyemon Kanazawa, the second son of Gyobuzayemon Kanazawa, to whom it had been transmitted from his father through his elder brother Seizayemon Kanazawa. Through the effort of Shimizu the art of surveying was systematized and extended, and he wrote several manuscripts according to his system, in order to transmit them to his pupils. At that time, another school which had come down from Yamasaki flourished also. But it was some years after that before the
books concerning the art of surveying were published. Indeed, a book named the Jishakuzan-kongenki, written by Yoichiyemon Hosaka in 1687, may be regarded as one of the earliest ever published, but its contents are rather poor from the standpoint of a textbook of surveying. Since Tokiharu Man-o published the Kiku-bunto-shu in 1722, however, several books in which the method of surveying is dealt with in detail, such as Ryochi sbinan by Shoko Murai or Kikugempo-choken-bengi by Dokwan Shimada, appeared one after another. Moreover, at the end of the 18th Century, the Chinese books relating to the European method of surveying, such as the Li-suan ch‘ian-shu or the Ch‘ung-cheng-li-shu became extant, so that the knowledge of surveying was spread gradually to wider circles.

As regards the actual work of land surveying carried out by the European method, its application was confined, for a long time, to the measurement of comparatively small portions of land, such as towns or villages. A map of Yedo, which was drawn by Seizaemon Kanazawa according to his survey in 1657, is undoubtedly one of the oldest, but it is not extant. A map of Yedo which was published by Hanchi Fujii under the nom de plume Ochikochi Doin, partly in 1690 and partly in the following few years, still remains. Some believe that this map was based on Kanazawa's, but that is not confirmed. It is told that Fujii had also surveyed the Tokai Highway.

As an official work of the Shogunate Government, the map of Japan was constructed first in 1644 and secondly in 1697. Of both of these maps, it is recorded that they were drawn in a certain definite scale, but it can never be admitted that they were made on the basis of actual land surveying. Later, in 1719, the celebrated Shogun, Yoshimune Tokugawa who was an amateur of astronomy, gave considerable assistance to the in-
roduction of the European science to our country, and ordered Kenko Takebe, an eminent mathematician, and others, to re-construct a general map of Japan. With the authority of the Shogun and with the talent of Takebe, it would not have been difficult to construct a map with great accuracy by executing actual measurements over the whole land. It is to be regretted that they did not make fundamental work, satisfying themselves by merely adjusting previous maps by the materials of azimuth surveys which were made at every two or three points of each province with reference to the high mountains situated in the neighbouring provinces. They constructed a small map in the scale of one ri to 6 bu, i.e., 1:216000. This map was lost, and of its true value little is known to us. During this period, some of the Feudal Lords measured and mapped their own domains, but none or very few of their works were conducted in a scientific manner.

A rough map of Japan drawn on a small sheet and containing only the names of provinces and some of the principal towns etc. is said to have been constructed for the first time by Gyoki, a Buddhist priest, in the 8th century; and such maps became numerous in the early period of the Tokugawa Government, and about the time of Empo (1673–1681) some such maps were already published. It is noteworthy that, at the beginning of Kwanbun (1661–1672) or somewhat earlier, Terutsuna Matsudaira, Feudal Lord of Koga, drew a map of Japan on a very small scale, according to the style of the so-called compass map, giving the rough value of latitudes on its margin. Maps of Japan which were drawn by foreigners before the beginning of the 17th century did not represent the Islands even in their rough form, while those published in the latter half of the same century showed more or less improvement, as the form of the coast lines became known to them to a certain extent by the voyages of Martin Gerrit-zoon Vries and others. The map of Japan given in the History of Japan, by Engelbert Kämpfer, who came to our country in 1690,
was drawn with the materials of domestic as well as foreign sources, and may be looked upon as a specimen of maps extant at that time. None of these maps, however, was satisfactory in its nature, showing nothing more than a rough form of the Japanese Islands.

In the 18th century no remarkable improvement was made in the map of Japan, till, in 1778, Genshu Nagakubo\(^1\) published a map named the Nippon-yochi-rotei-zenzu,\(^2\) which is known more popularly as the map of Sekisui,\(^3\) this being his literary name. Nagakubo spent many years in travelling round the Japanese islands, examining and correcting all kinds of maps then available; and the geographical knowledge acquired during his journey was the chief resource of his map. Thus, since this map was not based on the actual land surveying, though some astronomical data for certain places which had been roughly determined by astronomers seem to have been taken into account, it contained not a few errors; moreover, as it was drawn in the small scale of 10 ri to 1 sun, i.e., ca. 1:1300000, the minute configuration of the Islands was not shown. Notwithstanding these defects, it excelled the previous maps in many respects, so that it was welcomed by the people of all classes and passed through several editions.

Turning our attention again to the methods of surveying which were known to the Japanese at the end of the 19th century, it is found that the common methods necessary for topographical survey, such as the traverse, the method of intersection, taking offsets, etc., were quite familiar to them; the levelling then used was also similar in principle to that of the present day. The method of triangulation which is generally used for geodetic survey nowadays was not yet introduced, but the method of correcting the errors of measurement for a large portion of land, by means of taking the azimuths of prominent mountains from suitable points, and by observing the astronomical longitudes and latitudes of principal stations, was well

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(1) 長久保玄球  (2) 日本輿地路程全圖  (3) 赤水

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known. As to instruments, various kinds of measuring poles and ropes, plane tables, alidades, magnetic compasses and theodolites, were already in practical use; a spirit level, however, was not yet used, a plumb line or an instrument having a long horizontal groove filled with water being employed in its place.

The chief reasons, why the practical work of surveying did not for a long time develop fully, parallel with theories and instruments, were (1) that most of the so-called surveyors, being only the transmitters of the methods on paper, had no ability in conducting the work in practice, (2) that the construction of instruments then existing was so rough and rude that they were quite unsuitable to carry out the work for a large portion of the earth surface, (3) that, excepting some specially favourable circumstances, it was very difficult to conduct a work of surveying in the domain of a Feudal Lord. When Ino commenced the survey of Japan, however, all these difficulties were already removed; for, he was highly educated in astronomy and surveying, not only in theory but also in practice; he was equipped with accurate instruments, most of which had been constructed in the Kwansei\(^1\) era (1789–1800) in the European style, according to the design of Asada, Takahashi and Hazama; and his work was carried on under the protection of the Shogunate Government. And thus, after a lapse of 170 years since the European method of surveying had been introduced to Japan, a great practical work of land surveying was actually executed in this country.

**Ino's Method of Surveying.**

The method of surveying which Ino adopted in his work did not differ in many respects from that generally used by the Japanese surveyors. The only differences were that he conducted the work with the best appliances of all of the known methods in the most proper manner, and that he determined the positions of a great many stations by his own astronomical observations.

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\(^1\) 寛政
Ino surveyed all coast lines and roads by the traverse method. Their lengths were, as a rule, measured with the iron chain or the rattan rope; but in some special cases, such as measurements conducted on a boat, a long rope made of hemp fibres was used instead. In the early period of his work, even the measuring wheel or number of footsteps was sometimes utilized for determining the mileage of the highways. The azimuth of coast line or road was always determined by reference to a magnetic needle; and, as a rule, two magnetic compasses, each of which was mounted on a stout rod, were used, one for foresighting and the other for backsighting. The inclination of the route was determined in the first two years by an eye estimation, and in the latter years with a small quadrant of simple form.

In places where the actual measurement of distance was impossible owing to the unfavourable condition of the coast lines, the positions of principal points were determined by the method of intersection; and in such cases or when the traverse had been done only very roughly along a coast line, an accurate measurement along another even road joining two points of the coast line, which he called the Yokogiri, or a crossing, was always performed as a control,

From every suitable point in the route which Ino surveyed, the directions of such objects as temples, towers, high trees, hills or flags specially erected in the neighbourhood of the route were measured as often as possible with a magnetic compass, in order to determine the positions of these objects and also to adjust the measurement by the state of intersection of the azimuth lines directed to objects from various points in the route. For the same purpose, the azimuths of distant mountains or islands, were also measured accurately with magnetic theodolites at many points in the route where the circle of vision was broad. Most of the measured routes were closed and connected with each

(1) 横切
other at many points, so that the measurements consisted of many closed traverses, and this served to check the accuracy of the work.

The most important point of Ino’s work was, however, that he measured the astronomical latitudes of more than 1200 stations, which served as fundamental data to determine the length of the meridian arc and to test the result of the land survey. The method which he used to determine the astronomical latitude was a kind of relative method; that is, he measured the meridian altitudes of many fixed stars at every field station with an accurate quadrant, and compared them with those which had been measured at the standard station with the same instrument, so that the latitude difference between the field and the standard station was determined by taking the mean of the altitude differences of fixed stars.

Ino desired earnestly to determine the astronomical longitudes of stations at great distance from the standard station, and for this purpose he observed, in all possible cases, the solar and lunar eclipses which occurred during his excursions, with the eclipsemeter and the pendulum clock. But, as the chance was very rare that simultaneous observations at both a field and the standard station had been done fairly, he tried in later years to determine the longitude by the observation of the eclipses of Jupiter’s satellites.

Ino’s Opinion on the Magnetic Needle.

The use of the magnetic compass was made known gradually to the Japanese people. In the 6th century, it was imported from China through Korea; and in the period of the Tokugawa Government it was counted as one of the most important instruments for land surveying. But as the construction of the magnetic needle was very rude, being generally flat and short, it served only to indicate the magnetic meridian very roughly, and it was not seldom that the directions pointed by different needles
differed by several degrees from each other. Since it was cited in some books imported during the early period of the Shogunate Government that the direction of the magnetic needle does not generally coincide with the true meridian, this having been quoted in some of our books, e.g. Horekirekisho, it was very difficult for the Japanese surveyors to decide whether their differences came from the very nature of the magnetic needle or were merely instrumental errors.

Ino thought that the rude construction of the magnetic compass was a great hindrance to the development of the practical work of land surveying, and he exerted himself to construct a perfect magnetic needle. After a careful investigation the defects of previous magnetic needle, he constructed successfully a long slender needle having a quartz cap at its centre, mounted on a sharp steel pivot, and he found that all magnetic needles having such construction pointed one and the same direction, indicating no appreciable instrumental error. Then he proceeded to test whether his magnetic needles pointed the true meridian or not. But, at that time it happened accidentally that the magnetic meridian was nearly coincident with the true meridian, so that he could not detect any variation; and consequently he was led to a serious misunderstanding that all perfect magnetic needles point always the true meridian and that the deviations indicated by common magnetic needles are totally due to instrumental error. Thus he doubted the real existence of magnetic declination in all parts of the earth or at least in Japan, except in such special regions as volcanic districts where the ferromagnetic rocks are abundant and are ready to disturb the pointing of the magnetic needle. Ino's opinion on the magnetic declination having been as above, he never suspected the existence of such a phenomenon as the diurnal variation of magnetic declination.

Throughout the whole period of his work of land surveying, he always measured the azimuths of terrestrial objects with reference to the magnetic meridian, believing that it coincided with

(1) 寶城記書
the true meridian except in some abnormal cases. He, however, recognized the existence of instrumental error to a certain extent even in the accurate magnetic compasses made by himself. He therefore determined, as a rule, the direction of a coastline or a road with two magnetic compasses, and that of a distant mountain or an island with three or more magnetic theodolites.

### III. Ino's Instruments.

#### The Standard Measure.

In our country, the length of the standard measure had suffered frequent alterations since very remote times, and even during the period of the Tokugawa Government it was not fixed definitely, though the unit length called the shaku\(^1\) did not differ much from that of the present time. According to a tradition which has been believed by many of the scholars, it is told that Ino constructed for the use of his work of land surveying a new standard measure called the Setchu-shaku,\(^2\) or average measure, taking an average of the so-called Kyoho-shaku,\(^3\) which had been fixed by Yoshimune Tokugawa in the Kyoho\(^4\) era (1716-1735), and the Matashiro-shaku\(^5\) which was then widely adopted among carpenters, and that its length corresponded to 0.30303 meters. In the early period of Meiji, a copy of Ino's original measure was compared with a metric scale which was then taken as the standard meter of the Imperial Government, and therefore Ino's measure coincided exactly with the legal unit of measure of the present day. This tradition is, however, very doubtful, for not only is there no trustworthy basis, but there is no evidence to prove that the copy used for the comparison was the true copy of Ino's measure.

Recently, we discovered in a godown of Ino's family at...
Sawara two original measures which had been undoubtedly used by Ino himself, and we were able to learn clearly the length of his measure. One of these measures bears the name of a mechanician, Tanryu Tanaka, on its back surface, while the other is anonymous, though it was probably made by Yagoro Ono or his son Yasaburo Ono who had constructed most of Ino’s instruments. He will be mentioned in the following pages. The anonymous measure is made of a brass plate, 345 mm. long, 38.5 mm. wide and 3.5 mm. thick. On the surface of the plate, eleven parallel lines are drawn at equal intervals, parallel to the length of the plate; and perpendicular to these parallel lines, two lines are drawn to indicate the standard length of one shaku. The interval between these two lines is graduated into one hundredth parts by parallel lines and into one thousandth by diagonals. The scale is provided with a slide index, by means of which the tenth of the smallest division, i.e., 1/10000 shaku, may be estimated. The other measure is similar in construction, the only difference being that one end of the graduation terminates at one end of the scale.

The lengths of these measures were standardized by me in the College of Science of the Tokyo Imperial University, and the following result was obtained.

(A) Line measure : 0.30325 m. at 15° C.
(B) Line-end measure : 0.30336 m. at 15° C.

Thus, the difference of lengths existing between these two measures amounts to about 1/3000 of total length which is rather too large, to be looked upon as an error introduced by the deficiency of the art of graduation. But, it is very likely that an error of measurement amounting to 2 or 3 ten-thousandths of

(1) 田中数柳 (2) 大野彌五郎 (3) 大野彌三郎

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one shaku may enter, when we try to measure a length with these measures by a naked-eye estimation; it may therefore be guessed that the above-mentioned difference should have been neglected as a quantity having no influence in practical use.

It is very curious that Ino did not pay any attention to the influence of temperature upon the length of the standard measure, although thermal expansion was well known to Ino's contemporaries, and mercury thermometers were already constructed by the Japanese. This was perhaps because he thought the expansion coefficients of common metals to be too small to be taken into consideration. However, if we suppose the linear expansion coefficient of brass to be 0.000018 and the difference of temperatures in the hottest and the coldest season to be 30 °C, the standard measure will suffer a change of length for these extreme seasons by a quantity amounting to 1/1850 of the total length; consequently the length indicated by the standard measure will deviate from its mean length by a quantity equal to 1/3700 of the total length.

These considerations show that the unit of length adopted by Ino in his work of surveying corresponded to 0.3033 meters or 1.0009 shaku of the present legal system, the fluctuation from this mean value amounting to about 1/3000 of the total length.

The Measuring Pole, Rope, Chain and Wheel.

The measuring poles used by Ino were lost, but it may be guessed that each pole was made of hard wood having a square section and provided with metallic caps at both ends, its length being exactly 12 shaku.

Most of the measuring ropes used by the Japanese surveyors previous to Ino, were made of hemp fibres and though they were lacquered or varnished with 'shibu,' yet the change of their lengths by moisture and by the strength of the stretching force was too considerable to be overlooked. Hence Ino used such ropes only to measure the distance on the sea or the river, where the use of iron chain was inconvenient, and their lengths were
generally great, sometimes reaching 100 or 200 ken (1 ken = 20/11 m.)

Ino was one of the earliest who adopted the **iron chain** in practical work. Each link of his chain, which was made of iron wire of some 5 mm. diam., forming a small loop at each end, had an exact length of 1 shaku; and a chain consisted of 60 links, thus giving the length of 60 shaku or 10 ken. Marks denoting the end of every ken were attached to the chain. Such an iron chain was uninfluenced by moisture, but sometimes it was found very inconvenient, as its weight was very great and the iron links frequently got crooked, when the measurement was carried along a rocky and uneven road. On this account he also constructed rattan and bamboo bands of suitable length and used one of them when the use of the iron chain was unfit. He standardized the lengths of these ropes or bands by an iron chain before and after the measurement. But he thought nothing of the influence of temperature upon any of these measuring chains, bands, or ropes, while he studied carefully the relation between their lengths and moisture.

The **measuring wheel** which Ino used as an auxiliary instrument in the early period of his work is still preserved. This instrument consists of a wooden box mounted on four wheels, and is so made as to proceed in a straight line when it is pulled forward by a rope attached to it. Two of the wheels which play the principal part in measuring the length, have circumferences exactly equal to 2 shaku and are fixed on the axis which is put in connection with index wheels arranged in the box, so that the
distance rolled over by the principal wheels may be read from the graduations on these index wheels.

**The Small Magnetic Theodolite.**

Ino's small magnetic theodolite was sometimes called the Wankwa-rashin (compass hung in universal joints) or the Tsuyesaki-jishaku (compass mounted on a stick), because it was hung in universal joints and mounted on a wooden rod driven into the earth. This instrument was the simplest, most convenient and comparatively accurate one among Ino's instruments which he constructed for the land surveying; and that he could perform his grand work in a comparatively short time was greatly due to the superiority of this instrument. One of his small magnetic theodolites is now preserved in the college of Science of the Tokyo Imperial University, and it has the following construction.

The main body of the instrument consists of a circular brass box, the diameter of which is 10.9 cm. and the depth 2.7 cm. in the centre and 1.8 cm. in the margin. The bottom of the box is filled with lead in order to increase its stability, and the lead is covered with a silvered brass plate which forms the base of a graduated circle. The graduated circle which is also made of silvered brass and fixed in a position 0.7 cm. above the base, has an inner diameter of 9.5 cm. and is graduated accurately to every degree. A magnetic needle which is suspended on a sharp steel pin at the centre of the base is situated on the same level with the graduated circle. The needle is 9.35 cm. long, so that a very small interval is left between

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(1) 笠原 義誠  (2) 笠原 義誠

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its two ends and the margin of the graduated circle. The breadth and the thickness of the needle vary from 0.08 to 0.03 cm. decreasing towards both ends; the south seeking arm, however, is made somewhat thicker than the other in order to place the needle horizontally against the magnetic dip. A hemispherical quartz fitted to the centre of the needle as its cap is 0.2 cm. in radius, and a conical hole on the quartz has an angle at vertex nearly equal to 90°. The graduated circle and the needle are covered with a glass plate, and this glass plate is pressed tightly by a brass ring which forms the base of alidade. The alidade consists of a pair of brass plates, each of which has a vertical slit 4 cm. long and 0.04 cm. wide, and it is fixed in such a position that the sight line coincides exactly with the meridian line of the graduated circle. The compass box is suspended on a brass gimbal, so that it always maintains a horizontal position with sufficient stability.

For practical use, the gimbal is mounted, by means of hollow cylindrical attached handle, on the top of a stout wooden rod driven into the earth, and the whole instrument is rotated till the sight line of the alidade coincides with the direction to be measured, and then the reading is taken at both points of the magnetic needle, in order to avoid the error due to eccentricity. For convenience' sake, the angle on the circle is graduated in the reverse order, so that the reading expresses directly the magnetic azimuth; and therefore the instrument is often called the Gyakume-ban\(^1\) or more simply Gyaku-ban,\(^2\) which means a circle graduated in the reverse order.

Besides this, Ino made an instrument called the Jumme-ban,\(^3\) in which the circle was graduated in proper order. The graduated circle of this instrument was made to rotate in the compass box, and the reading was taken by an index attached to the alidade, after the meridian line of the circle had been so adjusted as to coincide with the magnetic needle.

\(^{1}\) 逆目盤  \(^{2}\) 逆盤  \(^{3}\) 順目盤
But, as the Gyakumeban was simpler in construction and more convenient in use than the Jummeban, Ino chiefly used the former in his practical work, and had more than ten of them, while he constructed only one or two of the latter.

**The Large Magnetic Theodolite.**

Ino's large magnetic theodolite was lost, but it may be inferred that it had the following construction. The graduated circle was made of a brass plate attached to a thick wooden plate. Its diameter was about 75 cm., and the graduation was made very minutely by a series of concentric circles and that of diagonals. A magnetic needle similar to that of the small magnetic theodolite was placed in a circular hole dug in one portion of the graduated circle. An alidade for the use of naked eye observation was fixed on a brass arm which might rotate freely round an axis at the centre of the graduated circle and served as an index for taking the reading. A telescope was mounted on a pillar erected at the centre of the index arm, and was made to move in the same vertical plane of the alidade. The focal length of the objective of the telescope was about 50 cm., and a cross made of silk fibre was placed at the focus. This instrument was mounted on a heavy metallic tripod, the total weight of the instrument and tripod amounting to more than 40 kg. The instrument was levelled by means of the plumb needles hung along the sides of the pillar, by adjusting three screws of the tripod; and it was so set that the magnetic needle coincided exactly with the meridian line of the graduated circle.

Ino also possessed a magnetic theodolite of the middle size,
having a graduated circle of 36 cm. in diameter. It was pro-
vided with a telescope, but the construction seems to have been 
very rude, though little is known of it.

The Semi-circular Magnetic Theodolite.

This was designed and probably constructed in 1803, as an 
instrument more convenient than the large magnetic theodolite 
and more accurate than the small one, and afterwards it was 
chiefly used in place of the large one.

One of the instruments of this type preserved by Ino's des-
cendant is made of a thick semicircular brass plate, 17 cm. in 
radius; the graduation is made directly to every 10' by means of 
concentric arcs and diagonals. An 
alidade, similar in form to that of 
the small theodolite, is fixed to a 
brass arm having its axis of rota-
tion at the centre of graduation; 
and a magnetic needle, 10 cm. long, 
is placed in a box in the middle 
part of the instrument. The instrument is attached to a thick 
wooden plate which is mounted on a wooden tripod. The horizon-
tality of the instrument is secured by means of plumblines attached 
to the tripod, and by adjusting the legs of the tripod suitably.

The Inclinometer.

To measure the inclination of roads, 
Ino used a small quadrant which was 
20 to 40 cm. in radius and graduated 
to every 30' or 20'. For practical use, 
he attached this quadrant vertically to a 
wooden stand, and rotated it around its 
axis till the radial line of 90° became 
parallel to the road in sighting a for-
ward mark through a small circular hole 
perforated along that radial line; and
then the inclination was read by the point of the plumb needle, hung at the centre of the graduation.

**The Astronomical Quadrant.**

As the small magnetic theodolite was the most meritorious among several instruments used for land surveying, the quadrant took the most important position among all astronomical instruments. Ino had two astronomical quadrants, having the radius of 180 cm. and 115 cm. respectively, and both are now preserved, in good condition, by his descendant at Sawara. Of these two quadrants, the smaller is more important, as it is a precious relic with which he determined the astronomical latitudes of more than 1200 stations, and has the following construction and dimensions.

The wooden frame which forms the main body of the quadrant consists of three straight wooden pieces and a curved one fastened tightly together by six wooden ties. Each of the straight pieces is 115.5 cm. long, 7 cm. broad and 3.5 cm. thick, while the curved one is 11 to 12 cm. broad and 3.5 cm. thick; and the latter is composed of three sheets of plate, combined in such a way that the wooden fibres cross each other to protect it from warping. A brass plate, 0.6 cm. thick, is fixed to the frame by more than 90 screws, and on the curved side the graduation is made to every minute of an arc for the range of 92° by means of 11 concentric arcs, 105.2 to 109.3 cm. in radii, radial lines for every 10' and diagonals drawn between

(Astronomical Quadrant)

Fig. 7.
every two neighboring radial lines, while on the three straight sides are drawn the radial lines corresponding to 0°, 45° and 90° respectively. On a brass plate attached to the back surface of a straight side, a radial line is drawn parallel to the line indicating 90° on the front surface, and the graduation is made for the range of 40′ on each side of this line. This graduation serves to adjust the quadrant in a proper position by means of a plumb, and to read the deviation when the position of the instrument was disturbed during an observation. Into a hole, 0.55 cm. in diameter, at the centre of concentric arcs, is pierced a steel bar which serves as the axis of rotation of a telescope and as the point of suspension for the plumb line, the ball of which is dipped into the water in a small case attached to the lower end of the back surface of the vertical straight side. The telescope consists of a series of lenses which are arranged in a brass tube inserted to a wooden tube, 117 cm. in length and 5.4 cm. square in section. The objective is a simple convex lens having the diameter of 2.8 cm. and the focal length of 71 cm., while the eye-piece consists of three simple convex lenses. At the focus of the objective, a cross made of silk fibre is placed, and a glass window is cut on the tube in order to illuminate the cross by a lantern. The index arm to which the telescope is attached is made of a wooden plate, 115 cm. long, 9.7 cm. wide and 1.9 cm. thick, covered with a thin brass plate; and the telescope is fixed, by means of adjusting screws, in two rectangular brass frames attached to the plate, so that its axis of collimation becomes parallel to the index line. A hole at one end of this arm fits to the axis of rotation at the centre of concentric arcs of the quadrant, and a clamp and a tangent screw are provided at the other end. The reading index is made of a brass plate of knife-edged form, and a reading up to 5′ may be taken by estimation.

The quadrant stand was lost, but originally it was so constructed of wood that it might easily be taken apart for convenience in transportation. A perpendicular axis, to which the
quadrant was attached, consisted of a rectangular wooden pillar, 200 cm. in length and 10 cm. square in section, having an iron pivot at each end; and its perpendicularity was secured by adjusting the position of an iron plate, in a hole on which the lower pivot rested. The quadrant was attached to the pillar, by a stout bolt pierced through a hole at a point near the centre of the mass of the quadrant, adjusted to its proper position by means of the plumb line already mentioned, and by fixing suitably an iron boss on the upper edge of the quadrant by the use of three adjusting screws attached to a small iron frame on the pillar, to which frame the boss was inserted.

The larger quadrant, 180 cm. in radius, is quite similar in its form to the smaller, but the construction of its stand, which was lost, seems to have been much larger and stronger, as it was not a portable instrument.

The Transit Instrument.

In most cases Ino utilized the quadrant to determine the local time at a field station; but when he wanted an accurate local time, as in the case of the observation of an eclipse, he used a transit instrument constructed specially for the purpose. Though this instrument is not handed down to us, it originally consisted of two wooden pillars, one 2 meters high and the other 1 meter high. To the longer pillar two small horizontal arms were attached, while to the shorter, which was erected about 2 meters north of the longer, one arm was attached. On each of the arms, a small brass pillow was mounted, and among these pillows a triangular net of fine threads
which served as meridian plane was stretched as shown in the figure.

The adjustment of the net was executed, first, by adjusting the plane of net vertically by moving suitably the brass pillar on B with reference to a plumb line hung at A, and secondly, by bringing the plane of net into the meridian on moving the brass pillow on C by an amount calculated from the preliminary observation of a circumpolar star or from that of two different stars, the difference of right ascensions of which was well known.

For practical use, an observer laid himself down on a sofa put under the plane of net, in such a position that the lines AD, BD and BC appeared to be a single line when they were seen by a single eye, and he watched the transit of fixed stars on this line. At the moment of the transit of every star, the observer gave a signal to assistant who read the corresponding time by means of a pendulum clock.

The Pendulum Clock.

Ino's pendulum clock was made in 1796 by Tozaburo Toda, a mechanician of Kyoto. It is now preserved by Ino's descendant, and it still works smoothly when the pendulum is put in motion. The construction of the clock is similar in many respects to that of the present day, excepting the arrangements of the escapement and the pendulum suspension. The wheel, con-
connected directly with the escapement, consists of a pair of rings fixed to a common axis, and each ring, 3 cm. in diameter, is provided with 10 saw-like teeth projecting alternately towards the opposite ring. The axis of escapement is situated horizontally between two rings, parallel to the planes of rings; and to this axis an iron piece having a triangular section is so attached as to control the motion of the wheel, leaving and catching alternately the teeth in accordance with the oscillation of the pendulum. The pendulum is suspended by hanging a hook fixed at the upper end of the pendulum stem to a small loop made of a silk string and attached to a stout brass beam projecting from the main frame of the clock. The pendulum stem is made of a simple iron wire, 59 cm. in length and 0.15 cm. in diameter, and in its lower part the minute screw is cut in order to adjust the position of the pendulum bob, which is made of brass and is 3.5 cm. in diameter. The weight, which serves to move the clock, is wound up by pulling a silk cord coiled on the drum in a direction opposite to that of a cord hanging the weight; but owing to the imperfectness of the design, it often causes the stoppage of the pendulum during the winding unless it is done very cautiously.

The index needles attached to the
clock indicate the number of oscillations, and not the time system generally adopted by the Japanese or by the Europeans; hence it is troublesome to convert the clock face reading to the usual time system. The number of complete oscillations of the pendulum in a day is about 59000.

The Eclipse-meter.

This instrument was used together with the pendulum clock to measure the local time corresponding to various degrees of obscuration during an eclipse, and was classified into two kinds according to the construction.

The so-called simple eclipse-meter was a telescope having in its focus a metallic frame to which a great number of parallel silk fibres were arranged at equal intervals, 25 to 40 per centimeter. For practical observation, the telescope was continuously moved during an eclipse, so that the image of the sun (or of the moon, in the case of a lunar eclipse) lay always between two definite threads, and the line joining the centres of the images of the sun and moon was perpendicular to the parallel threads. In the course of the eclipse, the time when the limb of the moon touched any of the parallel threads was read by the pendulum clock, the degree of obscuration at that instant being calculated from the number of threads which were included in the eclipsed part of the sun.

The other, which was called the accurate eclipse-meter, was a telescope having in its focus a circular brass box, in which a fixed octagonal net, made of silk fibre, and two needles, movable in a straight line by means
of micrometric screws, were provided. The treatment of this instrument for practical use was similar to that of the simple eclipsemeter, the only difference being that the degree of obscuration was calculated from the readings of micrometer, when the needles were so adjusted as to include the whole image of the sun and to include the uneclipsed part of the sun.

The Gnomon.

Besides the quadrant, Ino used also a gnomon to determine the absolute latitude of the fundamental station at Kuroyecho, in Yedo. The pillar of his gnomon was 384 cm. high and the base of it about 800 cm. long. On the top of the pillar a brass bar, 3 cm. in diameter, was attached horizontally, in order to throw its shadow on the base. For actual measurement, a fan shaped screen, having a small hole at its centre, was placed on that part of the base where the shadow of the bar was thrown, and through the hole an inverted image of the sun with that of the bar was projected on the surface of the base. At noon, the position of the screen was so adjusted that the image of the sun was bisected by the image of the bar, and that position of the image of the bar was marked on the base. Then the true height of the bar above the base, and the horizontal distance of the image of the bar from the foot of the bar were accurately measured.
by means of scales and a levelling instrument specially constructed for the purpose; and from these data the apparent altitude of the sun, and consequently the latitude of the station, were calculated.

**The Telescope.**

Ino possessed a number of independent telescopes, besides those which were attached to the magnetic theodolites and the quadrants, and these telescopes were used by the members of his surveying party to observe such phenomena as the eclipses of Jupiter's satellites. One of the largest telescopes transmitted to the present day consists of three lenses arranged in a set of paper tubes, which may be folded into smaller compass when not in use. The objective is a simple convex lens, of 4.5 cm. diameter and of 212 cm. focal length, while the eye-piece is made of two simple convex lenses. All lenses used in Ino's telescopes were made by Zembei Iwahashi, a native of Kaizuka in the Province of Idzumi, and their images are very clear, though they are chromatic.

**The Drawing Instruments.**

The scale use by Ino to draw maps was made of a brass plate, ca 30 or ca 15 cm. long and ca 2 cm. broad. Its thickness was ca 0.2 cm. along one edge and ca 0.06 cm. along the other, and the graduation was made along the thinner edge to every 2 rin (=1/500 shaku) for the range of a shaku or a half.

He wanted frequently to reduce the scale of original maps into one-sixth, and in such cases he employed the so-called Shukudzu-shaku or reducing scale. This was made of a brass plate, having the length of ca 90 cm. and the section similar to that of common drawing scale; and for the first ½ shaku, an ordinary graduation was made beginning at one end of the scale, while the remaining part was graduated with a scale six times as large as the normal scale, starting from the same origin as the ordinary.
graduation. None of the common drawing scales or the reducing scales are transmitted to us.

The protractors used by Ino were similar in form to those of the present day. The graduation was made to every 20', 30' or 1° on the margin of semicircular plate having a radius of 5 to 10 cm. He, however, preferred paper as the material of the plate, because he thought the metallic protractor to be inconvenient for practical use owing to its heaviness. Some of the paper protractors made by Ino himself still remain.

The compasses, the bow-compasses, the drawing pen and the dotted line drawer, which were used by Ino, did not much differ in form from those of the present time. Pencils, however, were not yet employed for the practical work of drawing, though their use was known to the Japanese in Ino's time. He used to draw the so-called Haku-kei, or white line, with a pin in place of a pencil.

Ino took all possible cautions and means to minimize the deformation of the drawing paper, but as it was impossible to get rid of this defect entirely, he always described the numerical values of the principal dimensions of the figure on every sheet of his original maps. For the first draft of maps, a kind of paper called Nishinouchi was used, while for the finished copy, which was plotted from the first draft, Minogami, glazed with a mixture of alum and glue, and pasted on the back with Toshi, Kizuki or Maniai, was employed.

IV. The Accuracy of the Measurement.

The Accuracy of the Measurement of Distance.

As already described, Ino did not take care as to the length of his standard measure, the error amounting to 1/3000 of its length; hence it is not at all surprising that the error of the
length of the standardized chain or rope sometimes reached an amount exceeding this value. Again, the kinds of error introduced into the measured distance on the earth differed widely in different cases, the nature of the measuring rope, the features of the road and the condition of the weather being the principal factors; but even in the cases when Ino measured an even road with the iron chain under favourable weather, an error amounting to some $1/2000$ of the total length should have been expected, in order to proceed with a speed of $8-12$ km. per $7-8$ hours, and if a rattan or a bamboo band was substituted for the iron chain, the accuracy of the measurement should have generally fallen to one half of that in normal cases, for such a band was not so steady as the iron chain, the length being easily affected by moisture and by the slight change of stretching force. In exceptional cases, when the distance was measured by a hemp rope stretched over the sea or the river, it is doubtful if the error was less than $1/200$ or $1/300$ of the total length. The errors of distance measurement performed with the measuring wheel amounted to $2/1000-3/1000$ in ordinary and to $6/1000-7/1000$ in extreme cases, so that no advantage was gained over using the method of counting the number of footsteps.

Though the accuracy of the measurement of distance was not constant even in one continuous road, it may be inferred that in lines such as the road connecting Yedo and Mimmaya via Shirakawa and Noshiro, the coast line of a part of the Province of Dewa and Echigo, the Tokai Highway connecting Yedo and Kyoto and the Sanyo Highway connecting Kyoto and Shimono-seki, which Ino surveyed with utmost caution with special purpose, the error was, on an average, about $1/1000$ of the measured length. On the contrary, the accuracy of the measurements of most of the coast lines was much inferior, as they were generally surveyed under unfavourable circumstances; and especially for the measurements of the coast lines of Mutsu, Idzu,
Kii and a part of Shikoku and Kyushu, where the work was conducted under various difficulties, there is no doubt that the error often reached 1/200 or 1/300 of the measured length, and even 1/100 in extreme cases.

The Accuracy of the Measurement of Azimuth.

To discuss the accuracy of the azimuth measurement, let us first consider the accuracy of the instruments used. The circles of magnetic theodolites were graduated very skillfully, so that we may safely say, that the graduation error never exceeded 1/6° in the smallest circle and 1' or 2' in the largest. But, in the smallest instrument, the error introduced by adjusting the sight line of the alidade to coincide with the meridian line of the graduated circle seems to have often amounted to (an order of) 1/6°, while in the larger one, a constant error caused by the discrepancy existing between the direction of the line of collimation of the telescope and the zero line of the index arm generally exceeded the error of graduation. In the instrument of semicircular form, the maximum error arising from eccentricity was 7' or 8'. Though Ino constructed his magnetic needles with the utmost care, it may be concluded from experiments made with his needles, that the error of pointing of an order of 1/6° was hardly avoidable; and as this error of pointing of the magnetic needles was common to all his various theodolites, the resultant accuracy of the instrument did not much differ by its dimension; the combined instrumental error of the largest theodolite was (of an order of) 1/6°, while that of the smallest may be adjusted not to exceed 1°.

The principal part of the error of observation was introduced, in the case of the small instruments, by reading the angle with reference to the points of the magnetic needle; and in the case of the large instrument, by adjusting the orientation of the instrument, by the magnetic needle. This principal constituent of the error of observation amounted to an order of 1/6° in both cases,
while the other constituents showed a tendency to decrease as the dimension of the instrument increased, so that the total amount of the error of observation was of an order of $\frac{1}{5}$ to $\frac{1}{3}$ for the small, and of $\frac{1}{15}$ to $\frac{1}{5}$ for the large theodolite.

Thus, the resultant of instrumental and observational errors was generally of an order of about $\frac{1}{5}$ for the large theodolite provided with telescope, and of an order of about $\frac{1}{3}$ for the smallest instrument; and this was surely one of the principal causes why Ino, after some years' experience, substituted the smaller theodolite of semicircular form for the largest one. As we have remarked before, Ino determined the azimuth of the route by duplicate observation performed with two small instruments, and the azimuth of the distant mountain or island by means of observations taken with three or more of the various kinds of instruments. It may therefore be concluded that the adopted azimuth (with reference to the true magnetic meridian at the time of observation) was accurate to an order of $\frac{1}{5}$ to $\frac{1}{3}$ for the measured route and to an order of $\frac{1}{15}$ to $\frac{1}{5}$ for the distant mountain or island.

As regards the magnetic declination, the influence of its diurnal variation, of which Ino was quite ignorant, can never be put out of consideration, if the mean magnetic declination of a place be actually zero. Though the actual state of the diurnal variation at the time of Ino is unknown to us, it is very probable that it did not very much differ from the present state, varying mostly from 8 o'clock a.m. to 3 or 4 o'clock p.m., and attaining to the maximum range of 5' to 10' in the summer. If so, Ino's measurements always having been conducted in the hours when the pointing of the magnetic needle was unsteady, added to the fact that the azimuth measured in the morning would have been too small, while that in the afternoon too large (the azimuth being counted in the clockwise direction), the error of the azimuth measurement was increased on the average by the amount of 2' or 3'.
Again, the mean magnetic declination itself was not really zero in most parts of Japan at the time of Ino. Its actual distribution over the whole of Japan may be found clearly to a certain extent, if we survey the true azimuths of mountains and islands at every point where Ino had measured their magnetic azimuths, and compared the results. But such a complete investigation had not yet been attempted, and only a few of the values of magnetic declination for different regions was deduced approximately in order to find the general state of its distribution. Comparing the magnetic azimuths of the summit of Mt. Fuji\(^1\) and of two peaks of Mt. Tsukuba,\(^2\) measured by Ino at Kuroyecho during the years 1802 and 1803, with their true azimuths deduced from recent measurements, it was found that \(\delta \approx 19'\) E for Yedo, while adjusting the data of Ino's measurements for the Island of Shikoku, surveyed in the year 1808, a result \(\delta \approx 30'\) to 35' W was obtained as the average value for that island. Although these numerical values can not be much credited, still we may safely say that, in the first epoch of Ino's work, the magnetic needle deviated slightly towards the east from the true meridian in the neighborhood of Yedo, while in the later epoch when he surveyed the western half of Japan, it deviated toward the west by a rather large amount, surpassing the instrumental and observational errors in that region. This agrees well with the results deduced from other materials for the Island of Kyushu and the region of central Japan.

As the value of magnetic declination was nearly constant for a small district of land, the effect of neglecting it on the final result was simply to turn the map of that district through an angle equal, but opposite to, the magnetic declination, without giving any deformation to the map. For a large region extending over several hundreds of miles, however, its influence was quite different in form; in other words, the final result of the latitude of

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\(^{1}\) 富士山
\(^{2}\) 筑波山
every station was not much affected, as the latitude was always controlled to a certain limit by the astronomical observation, while, on the contrary, the influence on the longitude of every station was very great, as there was no suitable means of preventing the admission of errors due to the magnetic declination. On this account, the accuracy of the final result for the longitude was much diminished, especially in the southern parts of the Islands of Shikoku and Kyushu.

The Accuracy of the Measurement of Latitude.

The graduation of the astronomical quadrant was so made as to read to 5" by estimation, but it is doubtful if the graduation itself was accurate enough for such an order; and if it had been so accurate, it can not be denied that in practical use, the actual error at some part of the graduated arc would have reached an amount more than the smallest readable unit, for the frame of the instrument might be sheared owing to the unsuitable mode of attachment of the instrument to the stand. Other principal constituents of the instrumental error were the flexure of the index arm and of the telescope, the want of parallelism of the axis of collimation and index line (that is index error), and the eccentricity of the index arm; of these, the last was most remarkable, causing an error more than \( \frac{1}{2}' \) at the maximum position, and the second reached often an amount of 2' or 3', though it might be easily eliminated by a combination of observations. Hence the total absolute instrumental error was generally large.

But the condition was quite different, when the quadrant was used as an instrument of relative measurements, by which only the difference of meridian altitudes of a fixed star at the fundamental and a field station was determined. In such a case, the first term of the instrumental error was naturally eliminated, and the result was affected only by the error of the second order. As the main part of Japan lies within 5 or 6 degrees south and
north of Yedo where Ino established his fundamental station, the instrumental error introduced into the result of his relative measurements was only a differential residual of error due to the displacement of the telescope within the range of 5 or 6 degrees. The amount of this differential error was of course different in different cases, but it was never so large as 1' or $\frac{1}{2}$', except, in a few special cases, and it seems that it was not very difficult to restrict the influence of the instrumental error on the final result of relative measurement to an amount less than 10'', if the observation was done for a great number of fixed stars.

Considering the errors of observation, there is no doubt that the error of bisection and the error of angle reading were comparatively small, while the error introduced by adjusting the quadrant to its proper position or the error introduced by determining the amount of its deviation from the proper position was rather remarkable. Especially, when the observations were made for north and south stars which followed one after another in a very short interval, the error in determining the deviation of the vertical side of the instrument from the true vertical sometimes reached an order of 30'', as, in such a case, the reading was taken while the plumb line was still vibrating. Again, it may be inferred that the discrepancy between the plane of the quadrant and the true meridian plane amounted often to 30' or 1°, so that an error of an order of 15'' was introduced in the result deduced from a pair of stars, passing the meridian north and south of the zenith in the middle altitude.

It may, therefore, be concluded that the resultant of the observational and the instrumental errors for a single observation of the relative measurement was generally of an order of 30'', and the error for the final result was decreased to a certain limit according to the law of errors, as the number of observations was increased. And as the final value of the difference of latitude of a station was generally deduced from observation of more than twenty stars, it was possible to restrict its error to an
order of 10", if the construction of the star catalogue and the method of reduction were reasonable.

The accuracy of the materials used to construct the star catalogue was not uniform and some of them were very inferior in quality, though Ino generally repeated the fundamental observation more than ten times for every star; moreover he was not careful enough to eliminate the index error, and he omitted wholly the corrections for nutation and aberration to reduce the observed value to a certain standard epoch, though he applied the correction for precession by rough estimation. Thus, the value of the star catalogue was very much reduced, so that the error of the apparent altitudes of stars, which consists of that of absolute measurement of altitude and that of the imperfectness of the method of reduction, reached sometimes an amount of 2' in extreme cases though generally it did not exceed 1'.

Again, in the reduction of observed materials obtained at a field station in order to compare them with the star places given in the catalogue, he neglected not only the corrections for nutation and aberration but also the differential correction for refraction. Of these, the neglect of the correction for aberration produced the most remarkable effect. The effect of neglecting the correction for nutation was comparatively small, for the most part of the star catalogue was revised several times by the materials observed at the fundamental station just before or after the excursions. The differential correction for refraction was generally very small, as Ino chose, as a rule, stars having high meridian altitude; but the error introduced by neglecting this correction had always a tendency to diminish the latitude difference numerically, that is to say, to decrease the latitude of every station situated in the north of Yedo and to increase that in the south of Yedo.

Thus, the latitude difference of every field station determined by Ino contained several kinds of errors, and the numerical amount of their resultant was very different in different cases,
depending on the weather, the number of observed stars, and the condition of observation itself, as well as the relation of dates of observations at the fundamental and the field stations, the choice of stars, and the magnitude of latitude difference though it remained within 30" in usual cases.

As the absolute latitude of the fundamental station at Kuroyecho in Yedo, Ino adopted the value of 35°40'30". This value was probably obtained by rounding up the final result deduced from several kinds of observations to 1/2', as he did in other cases; and it agrees well within the limits of this rounding with the results of recent measurement, which gave the value of 35° 40' 17". The difference of 13" between these two values, however, gave to observed latitudes of all field stations a constant tendency to be slightly larger than their true value.

The Accuracy of the Length of the Meridian Arc.

The value of 28.2 ri, which was adopted by Ino as the length of one degree of the meridian arc, was deduced by combining the materials of latitude differences obtained by astronomical observations and those of meridian components of distances determined by land surveying, for a good many of the stations situated mainly between 35° and 41° of latitude, in the northeastern part of Japan. Converting this value to the metric system, making use of the relation of Ino's one shaku=0.3033 meters which we have given before, we get the value of 110.85 km., and this value differs by 0.13 km. from 110.98 km. which is Bessel's value of the mean length of one degree of meridian arc lying between 35° and 41°. Thus, the error of the length of meridian arc adopted by Ino amounts to about one-thousandth of the total length; but if we consider that an error of such an order might be caused even by one only of the many factors which were most likely to produce the error, e.g., a slight difference between the observed and the true latitude difference, it is rather wonderful that the actual error was relatively so small.
Moreover, that Ino's value of the length of the meridian arc was slightly smaller than its true value, notwithstanding the fact that the neglect of a number of small corrections in his reduction had a tendency to make the result somewhat larger, gave an accidental advantage to the adjustment of the materials of land surveying for the region to the south of Yedo. For he considered the earth to be a sphere throughout his reduction, although that its true form is an ellipsoid of rotation was known to him through Lalande's Astronomia a few years after he had begun his work, and consequently the error of Ino's value of meridian arc was reduced to about 1/2000 at the place $\varphi = 34^\circ$ and to nearly zero in the vicinity of $\varphi = 30^\circ$.

On the contrary, the effect of the neglect of the ellipticity of the earth on the length of parallels was very unfavorable. The error introduced on them amounted to about $1/200$ in the region of $\varphi = 30^\circ$ to $\varphi = 40^\circ$, so that the adopted longitude of a point lying $5^\circ$ east or west of the prime meridian was greater than its true value by the amount of about $1.5'$, even in cases when there was no error in the actual land surveying.

The Accuracy of the Measurement of Longitude.

During the work of land surveying, Ino observed six solar and lunar eclipses and some twenty of the eclipses of Jupiter's satellites; but of these phenomena, only two of the former and a very few of the latter were observed simultaneously at both the standard and a field station.

The accuracy of the pendulum clock used as a time keeper was comparatively good, and it may be inferred that the change of its daily rate never exceeded $3^\circ$; but the method of determining the local time with the quadrant or the transit instrument was very rude, and it seems that the error of the local time measured at a field station often reached an amount far exceeding $10^8$, as even in the fundamental measurement in Yedo it sometimes surpassed this value. In addition to this, the phenomena themselves were
not sharp in their nature, so that it was inevitable, with Ino's instruments, to introduce an error of an order of $10^8$ for the observation of the solar eclipse, and of $30^8$ for that of the lunar and the Jovian satellites. Hence it may be concluded that the longitude of a station deduced by such astronomical observation generally contained an error of an order of $5'$ or more; as an actual example, the longitude difference between Shimoda and Yedo, which was determined by the simultaneous observation of the lunar eclipse on Dec. 16, 1815, differed from its true value by an amount as large as $27'$.

On this account, Ino could utilize none of his own observations of eclipses to control the value of longitude difference deduced from the materials of land surveying. The longitude difference between Yedo and Osaka, however, seems to have been checked by the astronomical means, for 7 solar eclipses and 11 or 12 lunar eclipses which occurred between 1795–1818, were simultaneously and systematically observed in the Astronomical Observatory of Yedo and the private observatory in Osaka. The latter was built by Shigetomi Hazama and equipped with accurate instruments, and Yoshitoki Takahashi showed that the longitude difference may be deduced accurately from the materials of these observations.

The Accuracy of Determining the Location of an Adopted Position.

In order to determine the position of a station, Ino proceeded in the following manner. First of all, he drew a map for every small portion of the measured route with the measured distances and azimuths, in the scale of $1/36000$, considering that small portion of land to be in a plane. Then from every point in the route, where the azimuth measurement for typical objects lying in the neighbourhood of the route had been made, lines were
drawn in directions corresponding to the measured azimuths of the objects, to examine whether all lines directed to one and the same object converge to a point or not; and if they did not converge to a point, the map was so corrected as to adjust the discrepancies in the most probable form. Similarly, the mode of convergency of azimuth lines for a distant mountain or island was also taken into consideration of the adjustment of the map. If there were two or more measured routes between two stations, the relative position of these stations was, of course, determined by the weighted mean of the measurements. On every sheet of the maps thus adjusted, the meridian and the perpendicular components of the distance between every two successive stations were measured, and finally, the meridian component was revised by comparing it with the result deduced from the astronomical observations.

The accuracy of the adopted position of every station for the meridian direction was therefore somewhat increased over that of the latitude difference determined only by the materials of the astronomical observations, and the error was always diminished to an amount less than 30”, with but very few exceptions. On the other hand, the error of the adopted position for the perpendicular direction, i.e., the error of the longitude difference, was much greater in its amount than that of the latitude difference. It showed a tendency to increase in proportion to the distance, as there was no suitable means of controlling the error caused by the magnetic declination and by the neglect of the ellipticity of the earth, together with the true error of land surveying. Owing to the want of the original records, it is difficult to show the accurate numerical value of this error for every station, but it may be inferred that in the region lying between Yedo and Kyoto or between Kyoto and Shimonoseki, where the terminal stations were connected by a number of measured routes running nearly in the east-west direction, the error of the longitude of every station due to the imperfectness of land surveying was generally smaller.
than that due to the neglect of the ellipticity of the earth, and
the error of the adopted value usually did not exceed 1'. In the
northeastern part of Honshu and in the Island of Kyushu,
however, the error of the adopted longitude often reached nearly
2', which amount is very seldom exceeded. For, in these regions,
most of the measured routes run in the north-south direction,
which is very unfavourable in getting rid of the influence of
magnetic declination on the longitude; moreover, disturbance
due to abundant volcanic rocks and remoteness of the regions
from the prime meridian increased the amount of error. This
error of longitude for every station in Japan would have been
diminished to about one half of the above mentioned amount, if
Ino had eliminated the influence of magnetic declination and had
taken proper and suitable steps in the reduction of the materials
of land surveying.

Mention must not be omitted of the fact that the accuracy
of the position of the stations in the Island of Ezo is far inferior
to that in Japan Proper, as that island was measured mainly by
Rinzo Mamiya with less accurate instruments; and the error
of longitude difference between two stations, one in the middle
part of the island and the other in the western part, generally
amounted to 2' or 3', and that between the two one in the
middle part and the other in the eastern part, often reached an
amount even more than 10'. The error of latitude, however,
was comparatively small, as it was controlled by the materials
of astronomical observations executed by Ino at a number of
stations lying along the southeast coast, and by Mamiya himself
at a few points on the northwest coast.

V. The Accuracy of the Map.

The Method of Projection adopted by Inō.

In order to construct a map of a large portion of land, Ino
subdivided the region into a number of small portions, each of
which was about 5 or 10 km. square, and the map of every such small portion was, as already mentioned, drawn by considering it to be a plane; then these maps were collected to make the map of a region extending to some 50 km. square, and again these maps of larger regions were combined to cover the whole region where the measurement had been performed. On the map containing a large portion of land, he drew meridians and parallels according to the so-called Sanson and Flamsteed’s projection, all parallels being represented by a series of equidistant parallel straight lines, and meridians by curved lines, with the exception of a prime meridian passing through the middle part of the map; and for the map of the whole of Japan, completed after his death, this system was also adopted.

Sanson and Flamsteed’s projection has this characteristic, that the ratio of the area on the map to the actual area is constant for all parts of the region contained in the map, but the property of conformity, which is one of the most necessary conditions of practical maps, is only approximately fulfilled in a small part near the middle meridian and is lost gradually as the distance from the middle meridian increases. Yoshitoki Takahashi, noticing the unsuitableness of this projection for maps of practical use, devised, in 1802–1803, a new projection resembling the conical projection, and proposed to Ino that he substitute it for Sanson and Flamsteed’s projection. But on several grounds this proposal was not adopted, till Ino, after he had finished the field work, began the construction of the map of the whole of Japan. As the main part of the Japanese Islands extends over 16 degrees of longitude and of latitude, the defect of Sanson and Flamsteed’s projection became very remarkable in the marginal part of the map containing the whole measured area, so that Ino could no longer use this projection and he himself contrived a projection, modifying somewhat that of Takahashi.

Ino’s new projection was to draw meridians and parallels by displacing the intersecting points of meridians and parallels
which were drawn according to Sanson and Flamsteed's projection, from the north parallel to the prime meridian, by the amount
\[
m \left\{\frac{\tan^{-1}\frac{\tan(90^\circ - \varphi)}{\cos \lambda}}{(90^\circ - \varphi)}\right\},
\]
where \(m\) denotes the length of the meridian arc for a degree, reduced to the scale of the map. It is clear that this projection was obtained tentatively and not as the result of mathematical discussion on the property of conformity. Curiously enough the projection enjoys the said property to a remarkable degree and is closer than any of the simple conical of Bonne's and of Soldner's projection. Hence, the map of the Japanese Islands would have been more reliable if it had been drawn by this projection; but unfortunately his plan was disregarded and the map of the whole of Japan actually completed by subordinate officers and pupils after his death was drawn according to Sanson and Flamsteed's projection.

**The Accuracy of Determining the Location of an Adopted Position.**

Though the projection actually adopted in Ino's map was not suitable for common use, yet the accuracy of the position of every station on the map would have been quite equal to that given in the preceding chapter, if the map had been drawn in proper manner. But, owing to carelessness in constructing the map, a new error, which may be called the drawing error, was introduced, so that the accuracy of the position of every station on the map was less than could have been expected from the accuracy of measurement. The amount of the new error was comparatively small for the map containing a small portion of land, but was very considerable for that covering a large region.

As mentioned before, Ino drew the map of every subdivided portion of land covering 5–10 km. square, by considering it to be a plane. This was the proper treatment, for the error caused by
neglecting the curvature of the earth's surface was insignificant for such a small area. In constructing the map of a region of some 50 km. square, collecting the maps of small subdivided portions, he did not, however, pay any particular attention to the curvature of the earth's surface, so that its influence was by no means negligibly small; and by this reason, a very strange fact that a closed traverse did not close on the map, even in the case where no error existed in the measurement, appeared on the first draft of his map. In order to adjust such discrepancies caused by the imperfectness of map drawing, he never applied the proper correction to all parts of the map, seeking for the true causes by which the discrepancies had been aroused; but he satisfied himself, in most cases, merely in tediously smoothing over the discrepancies. The accuracy of the position of every station on the map extending to some 50 km. square was, on this account, somewhat decreased from that determined by the measured materials, though the amount of the decrease of accuracy was generally so small that it was comparable to that due to the inevitable deformation of paper employed for drawing the map.

On the map of a larger region extending over the whole part surveyed in one continuous excursion, the meridians and parallels were drawn according to Sanson and Flamsteed's projection, and the map appears to have been drawn in a proper manner. But, on examining the first draft of the map, it is found that this map was constructed only by collecting the maps of regions of some 50 km. square in their original forms, and then by compressing somewhat the northern part of the resultant map towards the middle meridian, to smooth off the discrepancy caused by the effect of the meridian convergence. The adjustment was not, however, performed in a proper manner over the whole of the map; the discrepancy was apparently smoothed over by some simple correction, roughly estimated, to a comparatively small part of the map. Such a contradiction is often to
be traced, that in some parts of the map where the meridians and parallels intersect at angles differing by a pretty large amount from a right angle, the condition of conformity is nearly satisfied. Since the manner of constructing the map of a larger region was very rude, the accuracy of the position of every station on that map was much more reduced; and it is not seldom that the drawing error for the longitude of a station amounted to an order of 1', though the accuracy of the latitude remained nearly unaffected, as it was always controlled by astronomical observations and there was little chance of making drawing errors. It may, however, be remarked that, on the whole, the position of every station indicated by the meridian and the parallel lines on maps of this kind, does not differ so much from the truth as it is not in practical use.

The map of the whole of Japan, which was completed after the death of Ino, contains a very considerable drawing error, or rather mistakes, which make the coordinate lines on the map meaningless and give rise to serious misunderstanding. On this map, the prime meridian passing through Kyoto was indicated by a straight line intersecting perpendicularly all parallels, and the form of meridian lines was of course quite different from that on the minor maps, on each of which the meridian line, passing through the middle part of the map, was represented by a straight line. To draw a new map of the whole country by collecting the minor maps, it was necessary, on this account, to project every station on the new map according to its own longitude and latitude, or to trace the position of every station after all the minor maps had been so deformed that meridian lines on them were coincident in form with those on the new map. The map was, however, not compiled in such a manner, and, indeed, it is found on comparing this map with the minor maps, that it was constructed simply by collecting the minor maps in their original forms, the discrepancies which naturally occur in connecting the different parts being smoothed off by...
applying very tedious means. Consequently, the meridian lines on the compiled map lost their proper meaning, excepting in the region of Chugoku and a part of Tokaido, where the form of meridian lines on the minor map was accidentally equal to that on the compiled one. Especially was this true for regions of Kyushu and Ezo, where the divergence was so great that the meridian lines on the map and the map itself were quite independent of each other. The drawing error of the longitude of a station on the map increased generally with the distance of the station from Kyoto, amounting to 4°-5° in the eastern part of Hokurikudo, 6°-7° in the southern part of Kyushu, 10° in the Island of Hachijo, about 20° at Aomori, and finally attaining as large a value as 50° in the northern end of Ezo.

The nature of the drawing error thus introduced into the compiled map is, however, made clear; and if we draw anew a series of meridian lines on this map in such a way that, for the northeastern part of Japan the meridian line passing through Yedo is represented by a straight line perpendicular to the parallels, and for each of the Islands of Shikoku, Kyushu and Ezo the meridian line passing through the middle part of each island is straight and perpendicular to the parallels, leaving the original meridian lines only for the region of Chugoku and the western part of Tokaido, the value of the longitude of every station reckoned from new meridian lines corresponding to the region of that station shall be approximately equal to the value which Ino deduced from his measurements. The exception will be those stations which suffered irregular displacement on the map, lying in the boundaries of the minor maps.

The map of the whole country can therefore never be said to represent properly the result of the great work of Ino, but, on the contrary, it must be regarded as disfiguring it, as we shall naturally be led to a wrong conclusion if we discuss the accuracy of his measurement by the position of the stations indicated on

(1) 北陸諸 (2) 八丈島

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this map. The minor maps and the maps of small subdivided districts must therefore be looked upon as more precious relics, representing far more closely the result of his work than the compiled map.

It seems very probable that Ino, in order to construct the map of the whole of Japan, had this plan; first, to revise the minor maps themselves in their original drafts drawn after Sanson and Flamsteed's projection, as the maps extending over the region of 2 or 3 degrees square did not differ very much in form, where they were drawn after this projection or after Ino's new projection; secondly, to draw meridian and parallels according to his new projection on the paper on which the map of the whole country was to be represented; and finally, upon this paper to plot the position of every station, placing each of the revised minor maps on it in such a way that the coordinate lines on both maps should coincide as much as possible, and making necessary corrections due to the small difference existing between the forms of the coordinate lines of both maps. It is extremely to be regretted that the map of the whole country now existing was compiled in the illogical manner above sketched, so as to destroy the greater part of the true value of his work, the principal part of his plan being abandoned by his successors after his death.

IV. The Books written by Ino.

As Ino offered the greater part of the last half of his life to the work of surveying, most of the books written by him relate to that work, so that in addition to the maps and the Yenkai-jissokuroku, already mentioned, the principal books written by him are as follows:—

The Sokuryo-nikki\(^1\) or diary of surveying. 28 vols. In this

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\(^1\) 测量日記
diary, the actual state of conducting the work of surveying for the period extending from 1800 to 1816 is minutely described.

The Santo-hoiki\(^2\) or record of the magnetic azimuths of mountains and islands. ca 70 vols. This book is the record of the magnetic azimuths of mountains and islands measured at many stations with various kinds of magnetic theodolites, and gives very valuable materials for the discussion of the magnetic declination in Japan at the beginning of the 19th Century.

The Hokkyoku-kodo-sokuryoki\(^3\) or record of latitude measurements. ... vols. This book contains the differences between the meridian altitudes of fixed stars observed at numerous field stations and that at the fundamental station in Yedo. Only one volume of this book is transmitted to us, the rest, probably more than thirty or forty in number, being lost.

The Kosei-shikodo-hyo,\(^2\) or star catalogue giving apparent altitudes. ... vols. This star catalogue was constructed mainly by Ino's own observations made at the fundamental station in Yedo, and contains the apparent meridian altitudes of most of the stars greater than the 6th magnitude and visible in Yedo. As we have remarked before, though the process taken in constructing this star catalogue was not very rigorous, yet it must be looked upon as a precious relic, for it is together with that of Yoshitoki Takahashi, one of the oldest of the star catalogues compiled in Japan.

The Kokugun-chuya-jikoku\(^3\) or length of day and night at various districts. 2 vols. This book gives the time of sunrise and sunset, as well as the length of day and night, taking account of the twilight duration for various seasons and for various districts in Japan.

The Taisuhyo-kigenjutsu-narabini-yoho\(^3\) or method of constructing and using the logarithmic table. 2 vols. In this book a method for calculating the numerical value of common loga-

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\(^2\) ア・ソ・ト・ホ・イ・キ
\(^3\) ホ・ク・キ・ユ・ク・ホー・コ・ド・ソ・コ・リ・ヨ・キ
rithms, devised by Chokuyen Ajima\textsuperscript{5}) (1739–1798), an eminent Japanese mathematician, is explained, with actual calculations of the numerical values of common logarithms of 2–99, 101–109, 1001–1009, ..., 1000001–100009, &c., up to the tenth decimal place. One half of this book is lost now. It is said that Ino checked and verified the doubtful values of logarithms given in the table of the Shu-li-ching-yiin,\textsuperscript{6}) a mathematical work imported from China.

The \textit{Ino-Toka-ryu-ryochi-denshuroku},\textsuperscript{1)} or manuscript on Ino's method of land surveying, 2 vols. This book was written by Keijiro Shin Watanabe,\textsuperscript{2}) a pupil of Ino, after the death of Ino, in accordance with his will, whence it may be regarded as a work by Ino himself. It contains a brief description of Ino's method of land surveying and instruments for practical use. To the work are appended the trigonometrical table and the solutions of problems relating to sides and angles of a triangle.