The Japanese Magic Mirror

An Object of Art and of Scientific Study

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IMPORTANT ARTICLES were published on the Japanese magic mirror by Mr. Herbert Maryon and by Dr. Cyril Stanley Smith, respectively, in a recent issue of the present journal.[1] These works threw new light on the old and yet unsolved mystery of the magic mirror. It might be appropriate, therefore, to review, in the light of these results, those earlier studies on the magic mirror performed in Japan which have thus far been little known to the western world.[2] There will also be introduced, in the latter part of the present paper, evidence of an early interest in the Japanese magic mirror as found in one aspect of American college life during the late nineteenth century.

The scientific investigation of the magic mirror was initiated in Japan by some of the "foreign" teachers who stayed there in the early Meiji period (the late nineteenth century).[3] They had to come to Japan from Europe or America to teach science and technology at the newly established university in Tokyo. They were full of interest and expectation, seeing the novelties of an oriental country which had been kept isolated from the international world until about that time. They not only taught at the university but also applied their method of scientific study to Japan and its culture. For example, they conducted the excavation of shell-mounds and ancient tombs in various parts of Japan as well as gravity measurements and geological surveys of the Japanese islands. They made a chemical study of *saké* (Japanese rice wine) brewing, and of lacquer making. Their study of earthquakes and typhoons was very important. Among other things they also investigated the "magic mirror."

Because of the shiny and reflective qualities, metallic mirrors in general had been closely related to some primitive forms of religions. Particularly in China and Japan, they were often deified or taken as symbols of the object of worship, and the art of making elaborate mirrors was highly developed there. The mirrors with the "magic" quality were especially valued for their peculiar behavior. If the polished surface of a mirror of this kind was looked at directly, just like an ordinary mirror it reflected the objects in front of it. If, however, a bright light was reflected from the same surface of the mirror onto a white wall or screen, an image appeared with bright lines on a less bright background revealing the form of a Buddha or saint or other design on the back of the mirror. There were a considerable number of mirrors of this kind in Japan in the early Meiji period and they created a new sort of interest among the "foreign" teachers staying in Japan.

R. W. Atkinson, W. E. Ayrton and J. Perry from England, G. F. Berson from France, and T. C. Mendenhall from America, were those who actually carried out experiments on these age-old treasures of Japan, called "magic mirrors." The results of their inquiry also stimulated such young Japanese scientists as M. Goto, H. Muraoka, and K. Yamagawa, to undertake similar investigations. The works of these Japanese scientists were published, for the most part, in the Japanese language, while those papers by the western scientists were contributed to European periodicals with the exception of G. F. Berson's paper which was translated into Japanese and published in Japan.

In the first place, Robert William Atkinson hinted, in his brief paper,[4] that the pressure upon the back of the mirror "during polishing caused some change in the reflecting surface corresponding to the raised parts whereby the amount of light reflected was greater." Then, William E. Ayrton and John Perry reported the results of their examination of the magic mirrors[5] and they concluded that "the whole action of the magic mirror arises from the thicker portions being flatter than the remaining convex surface, and even being sometimes actually concave."

They attributed this inequality of curvature on the front surface to the stress "applied partly by the 'distorting rod' (a rounded iron rod used on the mirror surface to finish it), and partly by the subsequent polishing, which . . . tends to make the thinner parts more convex than the thicker."

Gustave F. Berson was the first to publish a scientific paper on the magic mirror in the Japanese language.[6] He applied the Newton ring method to measure quantitatively curvatures of various parts of the mirror surface corresponding to different thicknesses of the mirror plate. Thus, he was able to find out that the surface of the mirror was generally convex and the radius of the curvature was greater at thicker parts (for example, 5.1 m. at a thick part while 1.7 m. at a thin part). This confirmed the results of Ayrton and Perry. In his experiments, Berson also noticed that if a scratch was made by a nail on the back of the mirror, a concave line appeared on the corresponding part of the front surface. He assumed that when the mirror was being polished, the residual stress, which resulted from the solidification of the metal, caused such differences in the radius of curvature of various parts of the surface depending on the difference in the thickness of the mirror plate.

Berson's paper gave incentive to Makita Goto, a pupil of Yukichi Fukuzawa, to attempt experiments on magic mirrors with two other Japanese collaborators.[7] They were told that it was only relatively thin mirrors that showed the magic quality and that one can impart this quality to any metallic mirror by making the plate thin enough. Therefore, they took up coins and metallic mirrors, made them thin by whetting and polishing the surface, and succeeded in making their surfaces reflect onto a screen the figures which were on the back of the coins or the mirrors. Their further experiments revealed the following facts:

(1) If one has the raised parts of the back of the mirror supported against the surface of a table and polishes the face of the mirror, he will be able to give it a magic quality. However, if the edges only of the mirror were supported and its surface was polished *lightly,* then the same magic phenomenon would disappear.

(2) Dark lines are sometimes visible in the reflected image of a mirror. If one polishes the surface of such a mirror at a right angle to these lines, additional dark lines will appear in the image that are parallel to the direction of this polishing.

(3) If one grinds down the back of the mirror, removing the figures to reveal the plain surface, and then polishes the front surface, no pattern will appear in the reflected image.

(4) If one solders copper wires on the back of the aforesaid mirror so as to imitate the raised pattern of the back, and then polishes the front surface, he will see the figure of the soldered wires appear in the image produced by the reflected light from the surface.

(5) With a large magic mirror that gives a clear image of the pattern onto a screen, the image will get darker after applying strong polishing to the face with a whetstone if the raised parts of the back are supported, but the image will get lighter after applying similar polishing if only the edges of the mirror are supported.

Thus, they concluded that in the regular process of polishing while the back of the mirror was supported against a flat stand, the parts of the face opposite the raised pattern were more polished, became concave relative to the rest of the face, and consequently gave a bright image on a screen when light was reflected on the surface of this mirror. The method they employed to determine the relative concavity of the surface was to apply a whetstone lightly to the surface and decide those parts "concave" which the whetstone left unpolished.

As a sequel to the above paper, they reported additional findings. If a cut was made by a knife on the back of the mirror, a corresponding bright line appeared in the image that was produced by the reflected light from the front surface of the mirror. By examining the mirror surface with a whetstone in the same way as mentioned in the above, the part of the surface opposite to this cut was found to be "concave" (Fig. 1). Not only bronze plates but also copper, brass, or zinc plates (about ¾ mm. thick), which had been rolled, showed similar behavior. The same was observed even with thicker plates if the cut was made deep enough. Goto attributed this phenomenon to the internal tensile stress in the plate. To support his argument, he also showed that if a cut was made on one side of a stretched rubber plate, then a concavity appeared in the corresponding part on the other side of this plate. However, he did not present any clear statement as to the relationship between the magic quality of the mirror and the

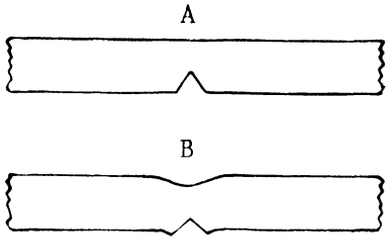

Fig. 1

Fig. 1A. A cut is made on one side of a plate.
Fig. 1B. A concave line consequently comes out on the opposite side of the same plate.

results of these experiments which he performed, nor did he seem to have read the works of Atkinson, Ayrton, and Perry in which some similar discussions were presented.

Han-ichi Muraoka also undertook experimental study of the magic mirror.[8] The first two papers he published concerning the magic mirror[9] were preliminary. Here he examined the face of the mirror by rubbing its edge with a fiddle-bow and observing how it vibrated, as seen in its reflected image on a wall. He also applied the Chladni method to examine the vibration of the mirror plate.

In his subsequent papers,[10] Muraoka reported the results of his major investigations. He stated that since the metallic mirrors with the magic quality were always very thin, he had a craftsman grind and polish several ordinary mirrors in order to make them as thin as possible and witnessed that all of these now acquired the magic quality. According to him, it had already been made clear that the concavity on the surface opposite to the projected parts of the back of the mirror was the cause for reflecting the pattern found on the back. Therefore, he wanted to find out what were the causes for making such a concavity.

He learned previously that in order to raise the concave part of the surface of a mirror it was the practice of the craftsman to rub that part with the edge of a metallic rod and then polish the whole surface evenly. Therefore, he made scratches with various tools on the surfaces of various brass plates, and found out that the parts of the surface where the scratches were made rose up, while the corresponding part on the opposite side sank in, and that this happened more noticeably with thinner plates. In performing this experiment he confirmed the veracity of the above-mentioned method used by the craftsman. This would, he thought, account for the fact that when a brass plate of irregular thickness was ground and polished uniformly, the surface of the thinner part rose. To confirm his point, he performed the following experiment:

Fig. 2

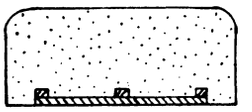

Fig. 3

Fig. 2. Diagram showing the joining of two brass plates to a piece of wood.
Fig. 3. Diagram showing brass plates immersed in Wood's alloy.

> . . . The author took two brass plates of the same size, bored a cross-shaped hole in one of them, soldered them together, and then polished the outside surface of the other plate and amalgamated it to make it a mirror surface. The part of this surface opposite to the hollow cross was now found to be convexly projected. On the contrary, a concave indentation was observed in a similar mirror with a projected cross shape placed on its back.[11]
>
> Thus, he concluded that the parts of the mirror surface opposite to the raised parts of the pattern on its back are concave is due to the fact that when the surface is polished or scratched the thinner parts protrude while the thicker parts do not (or do not protrude as much).[12]

While Goto tried to account for the phenomenon in terms of the difference in the amount of abrasion depending on the kind of support given when the mirror surface was polished, Muraoka proposed that the difference in the thickness of the mirror plate was mainly responsible for the same phenomenon. Muraoka maintained that this difference caused a varying degree of swell to the surface when it was being polished. His theory was supported, he assumed, by the following experiment which he performed:

(1) He prepared a brass plate in the shape of the character *ta*[13a] (a square plate with four smaller square holes in it), and soldered it onto another solid brass plate of the same size. Then, he applied sealing wax and joined the outside surface of the first plate to a piece of wood (Fig. 2). After polishing the outside surface of the second plate (the bottom surface in Fig. 2) with a whetstone, he placed mercury on this surface. Now this surface reflected the sunlight onto a screen and showed an image of the above character.

(2) Another set of two brass plates, the same as that in Fig. 1, was prepared and partly immersed into the surface of a piece of Wood's alloy, (Fig. 3). The bottom surface (Fig. 3) was polished with a whetstone to make it a mirror. Contrary to the previous experiment, this surface did not present any image of the above character at all. However, once the Wood's alloy was melted away, the same surface reflected a clear image of the above character on a screen. Experiment (1) may be explained by either Goto's theory or Muraoka's, but experiment (2) can be accounted for only by the latter, for as Muraoka said, there was no difference in the pressure nor was any different degree of abrasion involved in the latter experiment.

Muraoka's papers, translated into German, were published in the *Annalen der Physik und Chemie*.[14] Later, another paper of his, on the deformation of metal plates by polishing, was published in the same German journal.[15]

Thomas Corwin Mendenhall and Kenjiro Yamagawa are also known to have made and reported on their study of the magic mirror, but they did not publish their results. Thus, the articles mentioned above are practically all the papers on this topic published by native or visiting scientists in Japan during the Meiji period. They presented important observational experimental facts together with some speculative arguments concerning the cause of the magical behavior of the mirror. They were even thought to have sufficiently disclosed the secret. As a matter of fact, however, none of them did thoroughly clarify the actual process of producing such mirrors.

In recent years in Japan, the theme was taken up again for further scientific examinations. In 1958, Messrs. Kenzo Toishi and Rikuo Ishikawa published a paper on a Japanese magic mirror.[16] The mirror studied by them was made from two bronze plates soldered together all around the outer edge. They applied a modification of the Schlieren method to examine the small unevenness of the outside surface of the mirror plate, (with an image of Buddha) which was reflected by sunbeams onto a white wall, giving a bright image. They also made use of gamma rays to disclose the pattern on the reverse of this plate which was concealed from direct observation. Thus, they were able to find out that the part of the outside surface directly opposite to the projected pattern on the reverse was slightly concave and this was responsible for the above-mentioned image. They decided that such concavity was the result of polishing the mirror. In addition, they observed small scratches and a network of fine markings on the surface of the same mirror, and suggested that the latter was due to the cloth which must have covered this mirror for a very long while.

Mr. Teiji Yoshida is the owner of many metallic mirrors. According to his paper published in 1959,[17] there are different kinds of Japanese magic mirrors as follows:

(1) A mirror which is without noticeable unevenness on the front surface but when looked at displays an image completely unrelated to the pattern on the reverse. A mirror of this kind came from the thirteenth century and later. It was produced by applying a certain "imported" remedy on the surface of the mirror.

(2) A mirror that reflects the image of the pattern of its back onto a wall. This belonged to the early Edo period (the seventeenth century) and later. Its magic property was due to repeated polishing by which the mirror plate was made thin enough to produce this effect.

(3) A mirror consisting of two metallic plates and reflecting an image entirely different from the pattern visible on its back. It appeared in the middle of the Edo period (the eighteenth century) and later. Its secret depended on the same principle as that of (2) but worked more effectively because the back of the mirror surface was hidden from view.

(4) A mirror that reflects the image of the inlaid pattern on the front surface. It belonged to the late Edo period (the late eighteenth century) and later.

(5) A mirror with the inlaid front surface coated with tin, thus showing no features on the surface but reflecting the image under the tin which is different from the pattern on the back. It belonged to the late Edo period (the late eighteenth century) and later. During the early Meiji period in Japan, only the mirrors of the second group in the above classification seem to have been taken up by the foreign and native scientists. Mr. Yoshida himself attributed the magic quality of mirrors of this group to the minute roughness in the surface of the thinner part of the mirror where less light was reflected onto a wall as compared with the surface of the thicker part.

Very recently, Mr. Maryon[18] noticed on a Japanese magic mirror that a series of threads was added to the modelling to outline the features on the back of the mirror plate. He conjectured "It was to camouflage the punched outlines which were to be added to the work *after* the mirror with its modelled wax figure had been cast in bronze." He decided that the mirror was cast, then punched along the outline of the pattern on its back, and finally had its front surface repolished. The mirror's strange behavior resulted from this punching, he thought, because it caused concavity on the front surface corresponding to the features of the back of the mirror. Dr. Smith[19] then carefully examined another Japanese magic mirror and confirmed Mr. Maryon's theory, saying that "these parts (the parts of the design that appear on the image) and these alone have been outlined by a chased line which is visible only on close inspection." This is a very decisive and valuable observation which disclosed the secret of the magic of certain Japanese mirrors.

Although some of the above-mentioned investigators of the Meiji period, such as Atkinson, Ayrton, Perry, Berson, and Goto, had realized that a cut made on the reverse of the mirror produced concavity in the corresponding part of its front side, they did not relate this phenomenon to the process of making the magic mirror, nor did they actually notice in the existing magic mirrors such an effect as was pointed out by Messrs. Maryon and Smith in their recent papers. In fact, the scientists of that time seem to have been much occupied, as Mr. Maryon said, by the idea that oriental mirrors were cast and polished, not stamped or punched. However, convincing as it is, Messrs. Maryon and Smith's point of view may not necessarily be applicable to all magic mirrors. There could have been magic mirrors of some other category, as Dr. Smith himself also mentioned in the note he attached to his paper in reference to Dr. Joseph Needham's discussion on Chinese magic mirrors. So far as the present author has been informed, most of the Japanese magic mirrors do not show any marks of chasing or punching on either side.[20] Besides, Goto and Muraoka, respectively, were able to impart the magic quality to some metallic plates by means other than chasing, as has been discussed in the present paper. Therefore, it has to be admitted that we are not yet completely certain as to the secret of magic mirrors except for the kind recently clarified by Messrs. Maryon and Smith.

Now, going back again to the late nineteenth century, an American scene will be introduced which represents an early interest of American collegians in the Japanese magic mirror.

Edward Sylvester Morse,[21] then professor of biology at Tokyo University, temporarily returned to America, visited T. C. Mendenhall at Ohio State University in 1878, and proposed that Mendenhall come to Japan to teach physics at Tokyo University. Mendenhall accepted this offer, went to Japan and remained there until 1881. In Japan, he performed experiments on magic mirrors, among other things, and sent back some of the mirrors to his students at Ohio State University.

In the meantime, Morse resigned from Tokyo University in 1879 and then lived in Salem, Massachusetts. In the late spring of 1880, he was invited to give a lecture on "Things Japanese" at Ohio State University. Since he had been well acquainted with the Japanese magic mirror through his frequent visits to Mendenhall's laboratory and home in Tokyo, he must have on this occasion touched upon it in his lecture at the university in Ohio. [22]

At this time, the students of Ohio State University were discussing the publication of their annual. When they came to the question of naming the proposed publication, the editor suggested that it be called "the magic mirror". Therefore, one of the students wrote to Morse for the Japanese word for magic mirror and the characters to indicate it. On receiving this letter of inquiry, Morse went to a Japanese scholar in Boston and, from him, got both the word *Makio* and the characters standing for it.[23] Morse replied to the student promptly and enclosed with his letter a sheet of paper on which the characters *Ma Kio* had been drawn with a brush by the above-mentioned Japanese scholar (Fig. 4).

Thus, the first issue of the student annual entitled *The Makio* appeared in June 1880 and bore the characters on its front cover (Fig. 5). Certainly "It added materially to the mystery that seemed to envelop the enterprise, and its secret society promoter."[24] The salutation of this issue read:

> We desire that, like the real mirror, it may reflect from the surface the image of our outer college life, and under the strong sunlight of close inspection may reveal the hidden picture of inner college life.[25]

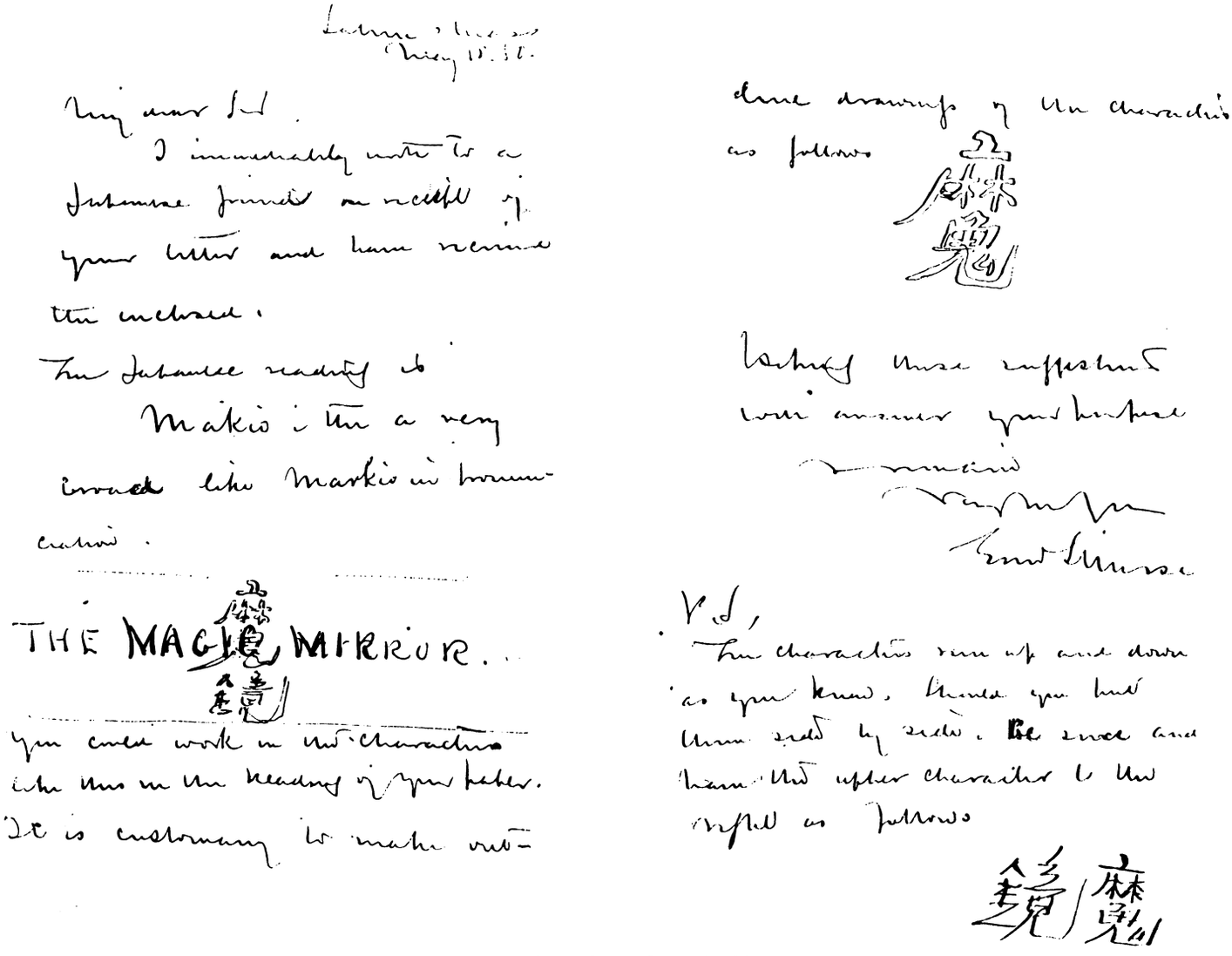

Fig. 4. E. S. Morse's reply to the student of Ohio State University.

Later, Mendenhall, after giving a short explanation of the Japanese magic mirror, said:

> "*Makio* is a most fitting name for an annual which is designed to reveal what is behind the scenes in college life."[26]

Oriental flavor was frequently apparent in this publication particularly in its cuts that dealt with oriental subjects. It was evident even as late as the early twentieth century, from cuts drawn by George Wesley Bellows, who was a student of Ohio State University during 1900-04 and became a famous American painter and lithographer (Fig. 6).[27]

It is very interesting to see that *The Makio* is still being published at Ohio State University. Nowadays, however, this student yearbook does not retain any oriental element except its name, nor does the meaning of the historic name itself seem to be clear to most of the students there.

Fig. 5. Ma Kio in characters appearing on the front cover of The Makio, Vol. I, 1880.

NOTES

1. Herbert Maryon, "A Note on Magic Mirrors," *Archives of the Chinese Art Society of America,* XVII, 1963, pp. 26-28; Cyril Stanley Smith, "Note On a Japanese Magic Mirror," *Ibid.,* pp. 29-31. The present author is indebted to Dr. C. S. Smith of Massachusetts Institute of Technology for the information he received.
2. Further details on this topic will be discussed by the present author in his paper, "The Magic Mirror as Studied in Japan during the Meiji Period," to be published in the *Japanese Studies in the History of Science,* No. 3, 1965.
3. Outside Japan, by this time, there were a few other investigators who had already undertaken the scientific study of the magic mirror.
4. R. W. Atkinson, "Japanese Mirrors," *Nature,* Vol. 6, May 24, 1877, p. 62.
5. W. E. Ayrton & J. Perry, "The Magic Mirror of Japan," *Proceedings of the Royal Society of London,* Vol. 28, December 12, 1878, pp. 127-148; W. E. Ayrton, "The Mirror of Japan, and its Magic Quality," *Nature,* Vol. 19, April 10, 1879, pp. 539-542.
6. G. F. Berson, tr. by Ono, "Nihon Seidôkyô Kisei Setsu," (On the Queer Quality of the Bronze Mirrors of Japan), *Gakugei Shirin* (Arts and Sciences), Vol. 7, 1880, pp. 276-289.
7. Makita Goto, *et al.,* "Nihon Seidôkyô Shiken" (Experiments on Japanese Bronze Mirrors), *Tôyô Gakugei Zasshi* (Oriental Journal of Arts and Sciences, hereafter *TGZ*), No. 22, 1883, pp. 35-37; No. 23, 1883, pp. 69-71.
8. H. Muraoka had studied physics in Germany under Kundt and Röntgen and was at this time a professor of physics at the School of Medicine, Tokyo University.
9. Han-ichi Muraoka, "Onshoku Shaga oyobi Onshoku Jinga" (The Reflected Images of Vibrating Mirror Plates and the Sand Figures Displayed on Them), *TGZ,* No. 14, 1882, pp. 107-109; "Onshoku Shaga no Ryakukai" (Comments on the Reflected Images of Vibrating Mirror Plates), *TGZ,* No. 25, 1883, pp. 133-137; No. 39, 1884, pp. 227-228.
10. H. Muraoka, "Makyô no Kai" (Note on Magic Mirrors), *TGZ,* No. 25, 1883, pp. 133-137; No. 39, 1884, pp. 227-228.
11. *Ibid.,* No. 25, p. 135, translated into English by the present author.
12. *Ibid.,* translated into English by the present author.
13. A Chinese ideograph, also used in Japan, that means a paddyfield or paddyfields.
14. H. Muraoka, "Herstellung der japanischen magischen Spiegel und Erklärung der magischen Ersheinungen derselben," *Annalen der Physik und Chemie,* Band 22, 1884, pp. 246-252; "Ueber den japanischen magischen Spiegel," *Ibid.,* Band 25, 1885, pp. 138-140.
15. H. Muraoka, "Ueber die Deformation der Metallplatten durch Schleifen," *Ibid.,* Band 29, 1886, pp. 471-484, also in *The Journal of the College of Science, Imperial University, Japan,* Vol. 1, 1887, pp. 69-84.
16. Kenzô Toishi & Rikuo Ishikawa, "Nihon Makyô no Ichirei" (On a Japanese Magic Mirror), *Kobunkazai no Kagaku* (Scientific Papers on Japanese Antiques and Art Crafts), ed. by Ichirô Ôga, No. 15, 1958, pp. 18-25.
17. Teiji Yoshida, "Nihon Makyô ni tsuite" (On Japanese Magic Mirrors), *Niigata Daigaku Kyôikugakubu Kiyô* (Memoirs of the Faculty of Education, Niigata University), Vol. 1, No. 3, 1959, pp. 1-12.
18. *Op. cit.*
19. *Op. cit.*
20. The present author is indebted to Messrs. Sadaji Yoshida, Kenzo Toishi, Rikuo Ishikawa, and Kunio Aoki for the information he received concerning the Japanese magic mirrors.
21. E. S. Morse (1838-1925) studied conchology under Louis Agassiz, and taught at Bowdoin College (1871-74) and at Tokyo University (1877-79). He was then director of the Peabody Museum in Salem until his death. On his visits to the Orient, he added to his knowledge of zoology a remarkable intimacy with Chinese and Japanese art, especially ceramics, and with the folklore and archaeology of both China and Japan. His collection of Japanese pottery was acquired by the Boston Museum of Fine Arts, and he served as its curator after 1892. Besides numerous scientific papers on zoology, ethnology, and archaeology, he was the author of *First Book of Zoology* (1875), *Japanese Homes and Their Surroundings* (1885), *Catalogue of the Morse Collection of Japanese Pottery* (1901), *Glimpses of China and Chinese Homes* (1902), *Mars and Its Mystery* (1906), and *Japan Day by Day* (2 vols., 1917).
22. J. H. Galbraith, "Beginnings of the Makio," *The Ohio State University Monthly,* Vol. 6, June 1915, pp. 13-18, particularly pp. 15 & 17.
23. *Ibid.,* pp. 14-15; Harwood R. Pool's letter of January 28, 1894, in Ohio State University Memorabilia, 1873-1885.
24. *Ibid.,* p. 14.
25. *Makio or Magic Mirror,* Vol. 1, 1880, p. 3.
26. Thomas C. Mendenhall, ed., *History of the Ohio State University,* Vol. 2, 1926, p. 189.
27. Incidentally, G. W. Bellows drew a portrait of T. C. Mendenhall.

Fig. 6. A cut drawn by G. W. Bellows for The Makio.