

Archaeomagnetism During the Old Tomb and the Nara Periods

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1 Introduction

Pioneer works in the field of archaeomagnetic studies were commenced by E. Thellier and O. Thellier (Thellier, *et al.*, 1959), Burlatskaya (Burlatskaya, 1961) and others. In Japan also, Watanabe undertook such studies as early as in 1959 and was followed by Yukutake and others (Yukutake, 1961; Yukutake, Horai and Nakamura, 1963). E. Thellier and Burlatskaya studied not only the variation of the direction but also the intensity of the geomagnetic field during the archaeological past; in other words, they succeeded in getting the variation of the geomagnetic field. Recently, measurement of the archaeomagnetic intensity has also been advanced in Japan. For instance, by means of Tertiary rocks, Momose (Momose and Nagata 1960, Momose, 1963) once measured the geomagnetic force.

For the present purpose, Momose again employed the same method to measure the geomagnetic intensity of archaeological materials obtained at the ancient sites in Nara (Nara : 奈良) and other districts and part of his studies was summarized together with some other results obtained by Nagata and Arai (Nagata, *et al.*, 1963).

It has been noticed by Tsuboi and his colleagues that some of the directions employed in the allotment of the land for houses and farms during the period from the end of the 6th century to the first half of the 7th century are nearly northward but considerably deflected westward as compared with the geographic north. If these directions in question had any relation to the geomagnetic north

in those days and if they were employed by any kind of geophysical method, Tsuboi's attention would be a matter of importance, because the present scholarship holds a firm belief that the people in those ancient days had no apparatus for recognizing the direction of the geomagnetic field. This question led us to carry out a more detailed archaeomagnetic survey for a solution of this and other related problems.

Fortunately, in Nara and its environs are found many ancient tile and pottery kilns whose employed dates have been exactly confirmed through the investigation based upon ancient manuscripts, findings from archaeological excavations and so on. This paper is a brief note of the archaeomagnetic directions measured from these tile kilns in Nara and its environs.

2 Materials

Hand specimens have been taken from the walls and floors of ancient kilns at eight sites in Nara and its environs. However, through measurement of the magnetic direction of these specimens, it has been confirmed that some of them are not usable because some measured directions are scattered and others are much weakly magnetized. Such kinds of magnetization may have been due to the insufficient heating in the kilns.

For this reason, I will introduce the results obtained from the samples from the following five localities:

| Sample No. | Locality |
|-----------------|---------------------------------------|
| Narayama No. 15 | 1315, Nakayama-cho, Nara. |
| No. 42 | Umetani, Kizu-cho, Soraku-gun, Kyoto. |
| No. 51 | Akishino-cho, Nara. |
| No. 52 | " " |
| Takakura No. 10 | Takakuradera, Sakai, Osaka. |

Significance of these samples lies in their fixed dates with high accuracy, as firm historical evidences support their chronologic situations. The dates of the samples from Narayama (奈良山) can be based upon the Imperial Edict about the removal of the capital that is recorded in the ancient official chronicles (Shoku Nihongi : 続日本紀). The "Shoku Nihongi" tells us that the removal of the capital from Fujiwara (藤原) to Nara took place in 710 A.D. The capital in Nara lasted for more than 70 years and was removed to Kyoto in 784 A.D. Accordingly the Nara period covers from 710 to 784 A.D.

The Narayama kilns were naturally employed during the Nara period. Dates of some of these kilns are more strictly limited. For instance, Narayama No. 42 was built for baking roof-tiles of Kofukuji Temple (興福寺) whose construction was started in about 713 A.D. and the kiln was employed for several years. (NARA NAT. RES. INST. CULTURAL PROPERTIES, 1959).

The kiln numbered Narayama No. 15 was employed for the period from 720 to 750 A.D.; and the kilns numbered No. 51 and 52 for the period from 740 to 750 A.D. (NARA NAT. RES. INST. CULTURAL PROPERTIES, 1962). The period of employment of Takakura No. 10 is supposed to range from 550 to 580 A.D. (YOKOYAMA and TANABE, 1963). Thus the dates of these kilns have been fairly well-known through historical investigations. This fact is fundamentally important for the present discussion.

3 Variations of Geomagnetic direction

In Table 1, obtained magnetic directions and intensities of kilns are put in relation to their dates of employment. After the specimens were left for 60 days in random directions, they again were measured. The directions again obtained from the samples at each locality were calculated by FISCHER's method by putting $P=5\%$, but the radius of circle of confidence α with respect to each group of samples was known to be small. Accordingly these samples are usable as the indicators of the archaeomagnetism. With regard to the thermal stability of these samples taken from certain several parts of kilns, fragments of the Sue pottery (須恵器) from Takakura No. 10 and roofing-tiles from Narayama No. 15 were used and the geomagnetic total force was measured. According to the results, these samples proved that they were heated enough, as their magnetic properties were known to be satisfactorily stable. Judging from this, the kilns from which the archaeomagnetic samples in question were taken are inferred to have been sufficiently heated.

Table 1. Employed times, magnetic directions, etc., of ancient tile kilns.

| Localities | Agys | Number of Samples | Directions | | α | Intensity 10 ⁻³ e. m. u. /gr. |
|------------------------|------------------------------|-------------------|------------|--------|----------|---|
| | | | D | I | | |
| Takakura No. 10 | 550~580A. D. | 3 | 15°30'W | 45°00' | 2°30' | 0.69 |
| Narayama No. 42 | 713 A. D. ~ Several years | 5 | 19°06'W | 51°19' | 2°42' | 0.84 |
| Narayama No. 15 | 720~750A. D. | 9 | 13°40'W | 50°59' | 3°0' | 1.52 |
| Narayama No. 51, 52 | 740~750A. D. | 7 | 14°39'W | 53°11' | 1°38' | 0.36 |

⁺ α is radius of circle of confidence of $P=0.05$.

With regard to the secular variation indicated by these archaeomagnetic samples, the time-range of all the samples covers only less than 200 years and the ages of the most samples are dated to be within the period from 713 to 750 A.D., so that it is difficult to trace the mode of variation curve of geomagnetism.

Fortunately, by courtesy of YUKUTAKE (YUKUTAKE *et al.* 1964), the variation

curve that he obtained from his data of the volcanic products of Mihara volcano was offered for our use.

We have taken his curve into consideration to draw a curve of the points newly obtained.

In Fig. 1, solid lines indicate the variation curve drawn by YUKUTAKE and others (YUKUTAKE *et al.* 1964). Broken lines indicate that of WATANABE (1959) and thick solid lines indicate that of the present authors.

As to our points, it is difficult to connect them to each other because they are located very closely during the period from 713 to 750 A.D. The change in declination seems as big as 5° for 20 years or so from 716 to 735 A.D., so the gradient of declination curve will be very steep if we try to connect these points directly.

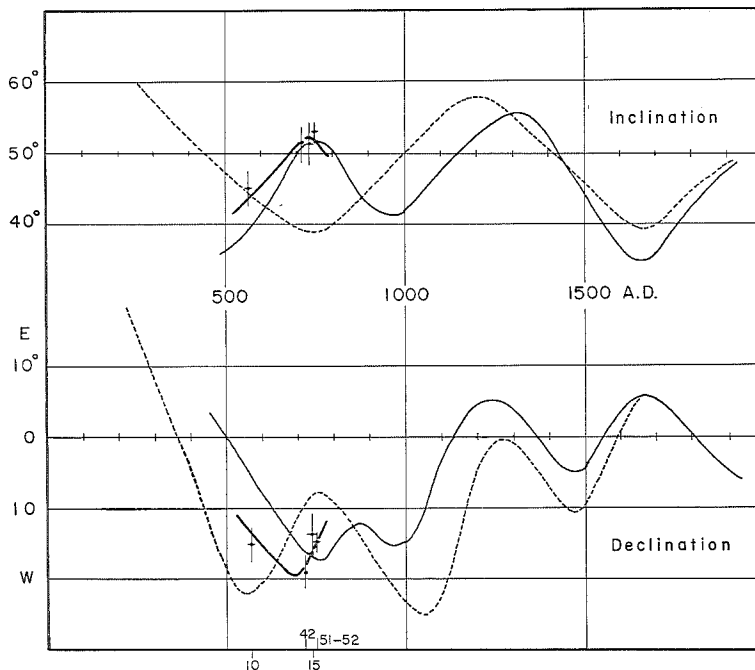


Fig. 1. Diagrams showing time variations of inclination and declination of the geomagnetic field. Upper : Variation in Inclination, Lower : Variation in Declination. Solid lines : by Yukutake and others, Broken lines : by Watanabe, Thick solid lines : by the present authors.

On the other hand, the change in inclination will be analogous to the YUKUTAKE and others' curve, if we connect a point from 550 to 580 A.D. (though we have only one point in the 6th century) with the points in the 8th century. The variation curve of declination was drawn with reference to the YUKUTAKE

and others' curve but it does not coincide with, though analogous to, their curve as seen in Fig. 1.

According to our curve newly drawn, the declination seems to have attained the westward maximum in about 690 A.D. during the period from 550 to 750 A.D., whereas the inclination seems to have attained the maximal value in about 730 A.D.

It would be appropriate, before closing this discussion, to express our gratitude to Prof. KUNIO KCBAYASHI who provided us with an encouraging suggestion about this study and helped us writing it in English. And we are also indebted to Drs. T. YUKUTAKE and K. NAKAMURA of the University of Tokyo for their kind offer to help us with their valuable opinions and to Mr. K. YOKOYAMA of Nara National Research Institute for his kind cooperations.

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* = in Japanese