ESTIMATING THE WITHERS HEIGHT OF THE ANCIENT JAPANESE HORSE FROM HOOF PRINTS

Masami INOUE* and Hajime SAKAGUCHI*

Summary

Data on the ancient Japanese horse is so scarce that the horse type and the route of entry from the Eurasian Continent have not yet been known. Recently, numerous hoof prints have been discovered at the Shiroi site, Central Japan. The prints were covered with pumice layer which fell in the Kofun period (6th century AD). Remains of the horse itself have not yet been found at this site. We have been trying to estimate the withers height of the horse by measuring the hoof prints and by analysing them. We have come to the conclusion that the Shiroi horse is the same medium-type as the native Kiso horse which has about from 125 cm to 135 cm withers height. Our analytical procedure is as follows:

1) Measurement and analysis of approximately 2,300 good samples of the hoof prints from among 40,000 samples. The most frequent statistical class of forefoot hoof print width is from 106 mm to 110 mm.

2) Experimental measurement of the hoof and hoof print of a native horse. We realize very little differences exist between the size of the hoof and of the hoof print.

3) Examining of the interrelationship between the hoof size and withers height in the native horses and Thoroughbred. Our conclusion is that they are closely interrelated.

4) Comparing the hoof width of the Shiroi horse with the modern horse. The modern horse in Japan can be classified into three types: the native small-type horse (Tokara horse; average width of forefoot hoof print 85 mm), the native medium-type (Kiso horse; average width of forefoot hoof print 105 mm), and the

Résumé

Estimation de la hauteur au garrot des anciens chevaux japonais à partir de leurs empreintes de sabot.

Les données sur les anciens chevaux japonais sont si peu nombreuses que ni le type de cheval ni les modalités d'immigration à partir du continent eurasien ne sont connus pour l'instant. Récemment, de nombreuses empreintes de sabot ont été découvertes sur le site de Shiroi, au centre du Japon. Les empreintes étaient fossilisées par une couche de cendres volcaniques datée de la période Kofun (VIe siècle ap. J.-C.). Les restes des chevaux eux-mêmes n'ont jamais été trouvés jusqu'à présent sur le site. Nous avons tenté d'estimer la taille au garrot de ces chevaux en mesurant et en analysant les empreintes de sabot.

Nous avons abouti à la conclusion que le cheval Shiroi était du même type (taille moyenne) que les chevaux autochtones Kiso qui mesurent entre 125 et 135 cm au garrot.

Notre procédure analytique s'est établie de la manière suivante :

1) La mensuration et l'analyse d'environ 2 300 empreintes sélectionnées parmi 40 000. La largeur la plus fréquente des traces d'antérieurs s'établit entre 106 et 110 mm.

2) Les mensurations expérimentales de sabots et d'empreintes de sabots du cheval autochtone actuel ont démontré qu'il existe un très faible écart métrique entre les deux.

3) L'examen des relations entre la taille du sabot et la taille au garrot chez les chevaux autochtones et d'élevage a fait apparaître une étroite corrélation entre les deux.

Zusammenfassung

Zur Ermittlung der Widerristhöhe antiker Pferde Japans mit Hilfe von Hufabdrücken.

Meßwerte von antiken japanischen Pferden sind bis heute so selten, daß bisher weder der Pferdetyp noch die Einwanderungsroute vom eurasischen Kontinent her bekannt waren. In Shiroi, Zentraljapan, sind neuerdings zahlreiche Hufabdrücke entdeckt worden. Die Abdrücke waren von einer Bimssteinschicht überlagert, die aus der Kofun-Periode (6. Jh. n. Chr.) stammt. Überreste der Pferde selbst sind nicht erhalten geblieben. Es wurde versucht, durch die Aufnahme der Hufmaße die Widerristhöhe der Pferde zu ermitteln. Wie es scheint, waren die Tiere von demselben mittelgroßen Typ, wie die heutigen Kiso-Pferde, die Widerristhöhen zwischen 125 cm und 135 cm aufweisen.

Bei der Untersuchung wurde folgendermaßen vorgegangen:

1. Aufnahme und Analyse von rund 2.300 Hufabdrücken. Die Breite der Vorderhufabdrücke liegt zwischen 106 mm und 110 mm.

2. Vergleich zwischen den Hufmaßen eines rezenten Pferdes und dessen Abdruck. Die Unterschiede sind offenbar gering,

3. Untersuchung der Beziehung zwischen Hufgröße und Widerristhöhe anhand rezenter Pferde.

4. Vergleich der Hufbreite zwischen den Pferden von Shiroi und modernen Tieren.

Die rezenten Pferde können in Japan in drei Typen unterteilt werden: den einheimischen Kleintyp (Tokara-Pferd; Durchschnittsbreite des Vorderhufab-

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recent large-type from abroad (Thoroughbred; average width of forefoot hoof print 132 mm).

4) Comparaison entre les largeurs de sabots des empreintes de Shiroi avec celles des chevaux modernes. Au Japon, ces derniers se divisent en trois types : les chevaux autochtones de petite taille (Tokara ; longueur moyenne de l'empreinte antérieure = 85 mm), les chevaux autochtones de taille moyenne (Kiso; 105 mm), et les chevaux de grande taille introduits récemment (Thorough bred; 132 mm).

druckes: 85 mm), den mittelgroßen, einheimischen Typ (Kiso-Pferd; Vorderhufabdruck: 105 mm) und den importierten Großtyp (Vollblut; Vorderhufabdruck 132 mm).

Key Words

Japan, Ancient, Horse, Hoof-print, Withers-height, Estimation.

Mots clés

Japon, Ancien, Cheval, Empreinte de sabot, Taille au garrot, Estimation.

Schlüsselworte

Japan, Antike, Pferde, Hufabdrücke, Widerristhöhe.

Introduction

Japan has many volcanoes, and volcanic eruptions have affected wide areas from earliest times to the present. Many sites under the tephra have been excavated in Gunma Prefecture, Central Japan and the Shiroi site is one of these (fig. 1). It was covered with a thick layer of pumice, under which numerous hoof prints have been discovered. The pumice undoubtedly fell in the late Kofun period, during the 6th century AD. The horses which left hoof prints at the Shiroi site were thus from the late Kofun period.

Remains of the horse itself have not yet been found at this site, and there are only ten studies for estimating the withers height of the ancient Japanese horse in the Kofun period from bone length. So we have been trying to estimate the withers height of the horse by measuring the hoof prints.

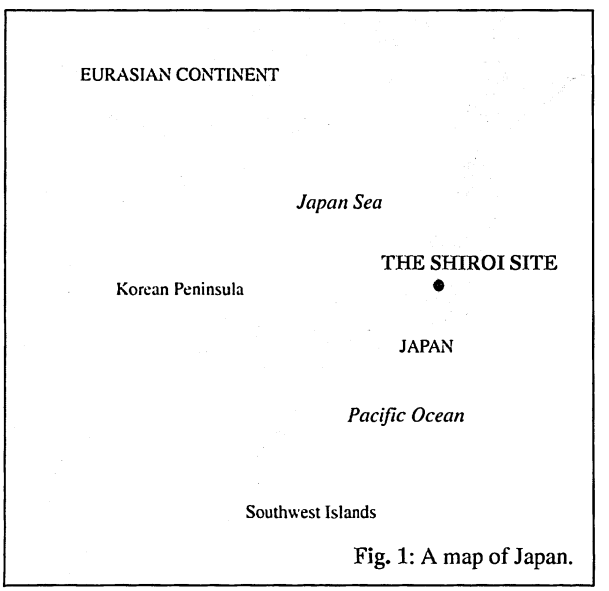

Fig. 1: A map of Japan.

An outline of the horse's studies in Japan

The period from the 3rd to the 7th century is called the Kofun period in Japanese history (fig. 2). The Kofun period is before the ancient Japanese state formed and it is characterized by the mounded tombs which are called Kofun. They show the emergence of powerful families, especially huge mounded tombs which are constructed in keyhole shapes. The excavated horse bones increase from the Kofun period. Horse-trappings, harness and earthenware horses appear at that time (fig. 3).

The important studies regarding the horse in Japan are presented below.

There are eight varieties of native horses in Japan. Dr. Hayashida classified Japanese native horses into two types. The small-type is from about 108 cm to 122 cm in withers height. The medium-type is from about 127 cm to 137 cm. Then he advocated that the small-type horse came to Japan from south-west China by way of the south-west Islands in the Jomon period and the medium-type horse came from Mongolia by way of the Korean Peninsula in the Yayoi period (Hayashida, 1978). Besides, he measured withers height and each bone length on Japanese native horses, the Thoroughbred and the Arab, and he devised a mathematical formula for estimation of withers height from the length of each bone in the horse (Hayashida and Yamauchi, 1957). This mathematical formula continues to be used for excavated horse bones.

Dr. Nishinakagawa *et al.* (1991) collected cattle and horse bones which were excavated all over Japan. Then he stated that horses had been introduced to Japan by way of the Korean Peninsula from the Yayoi period on.

Dr. Nozawa (1992) analyzed genes which are contained in the native horse's blood and he came to the conclusion that the small-type horse cannot be classified sepa-

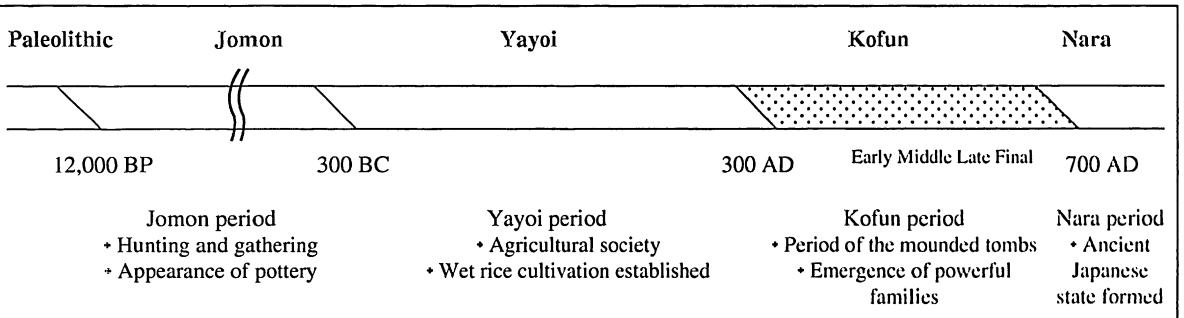

Fig. 2: An outline chronology of Japan.

Fig. 3: The earthenware horse (Haniwa horse).

rately from the medium-type horse in Japan, so that only the medium-type horse came to Japan. Then that medium-type horse adapted itself to the environment. As a result, it became the small-type in the South-west Islands.

Dr. Matsuura (1983) analyzed some horse bones that were thought to be from the Jomon period by fluorine which was contained in the bones, and he came to the conclusion that the bones were much older, from the 12th century AD.

A. Matsui (1990) stated that horses probably came to Japan in the Kofun period and the practice of riding horses began at that time, because the horse-trappings appeared from the Kofun period in Japan.

From the above-mentioned notions, horses are generally thought to have come to Japan from the Eurasian Continent in the Kofun period, and to have been closely concerned with human society.

An outline of the Shiroi site

The Shiroi site is on the river terrace at the junction of the Tonegawa river and the Agatsumagawa river. The Shiroi site is 190 m above sea level, and 15 m above the river bed. At present this area is used as farmland.

The horse hoof prints have remained on the land surface from the Kofun period, overlaid by from 50 cm to 120 cm thick layer of pumice, 1.3 m under the ground surface. The Shiroi site is located about 10 km east-north-east from the volcano. The pumice kept the hoof prints in good condition. About 40,000 hoof prints have been uncovered in the 50,000 m^2 excavation area (fig. 4). The hoof prints' direction is irregular and we have found two walking tracks.

Moreover, there are some ridges which look like a low bank, and some foot paths and some farmland which were not in use when the eruption occurred. From such a state, it could be seen that this area was being used as a pasture when the volcanic eruption occurred.

Identification and proof of horse hoof prints

These circle prints were identifiable as horse hoof prints from having some characteristics of prints, as follows:

(1) Forefoot hoof print distinguishable from hind hoof print (figs. 5, 6, 7).
We can distinguish between a forefoot hoof print and hind hoof print. This is because the forefoot hoof is slightly wider than the hindfoot.

Fig. 4: The Shiroi site (White circles are hoof prints).

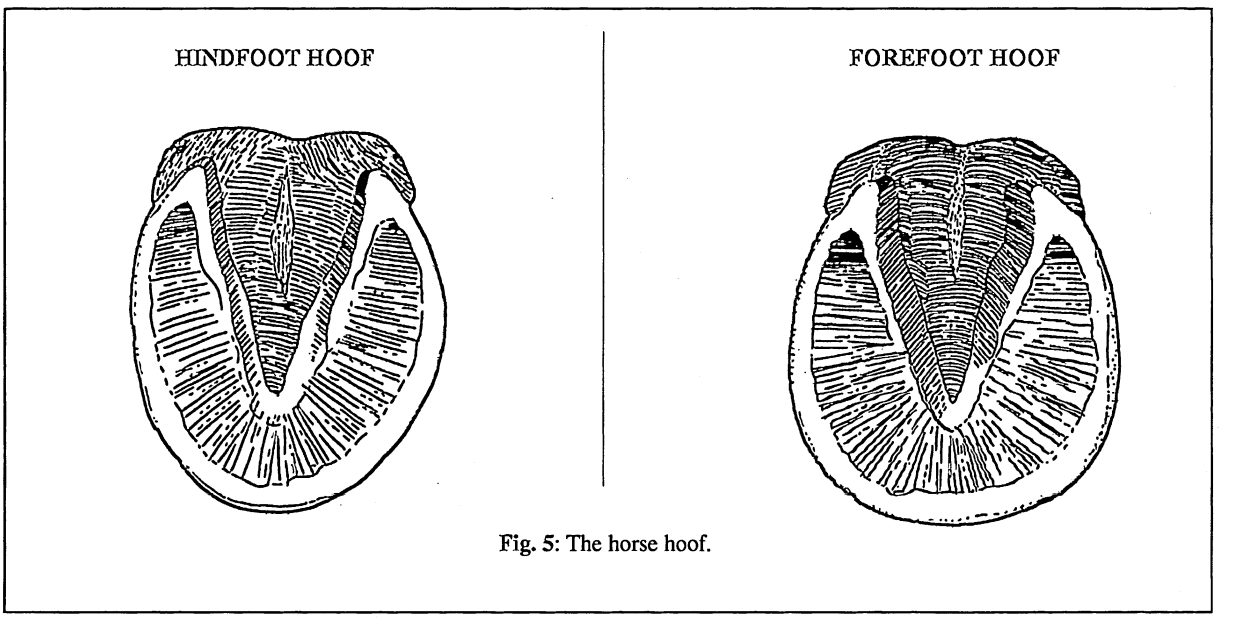

Fig. 5: The horse hoof.

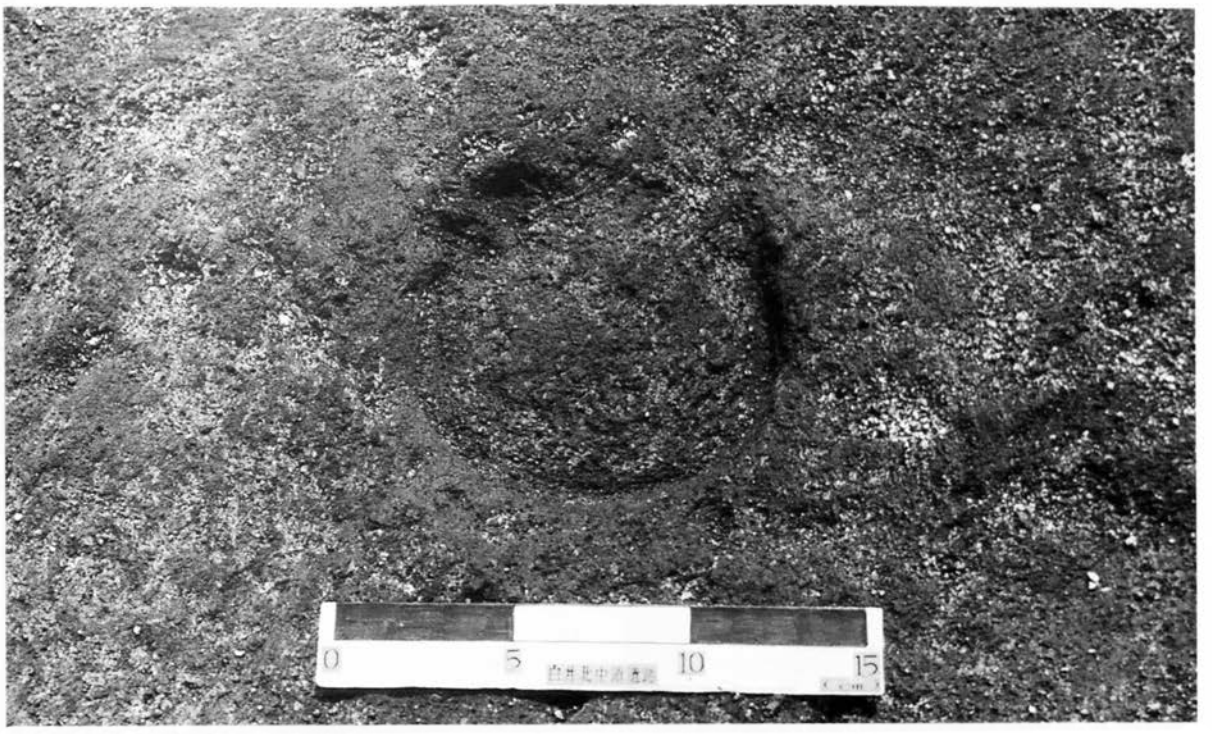

Fig. 6: The horse hoof print (forefoot).

Fig. 7: The horse hoof print (hindfoot).

Table 1: The frequency distribution of hoof width.

Hoof width (mm)	Shiroi forefoot hoof prints		Shiroi hindfoot hoof prints		Tokara forefoot		Kiso forefoot		Thoroughbred forefoot	
	Number	Ratio%	Number	Ratio%	Number	Ratio%	Number	Ratio%	Number	Ratio%
f ≤ 45	0	–	0	–	0	–	0	–	0	–
46 ≤ f ≤ 50	2	0.2	3	0.4	0	–	0	–	0	–
51 ≤ f ≤ 55	2	0.2	1	0.1	0	–	0	–	0	–
56 ≤ f ≤ 60	4	0.4	13	1.6	1	2.2	0	–	0	–
61 ≤ f ≤ 65	8	0.9	17	2.1	0	–	0	–	0	–
66 ≤ f ≤ 70	14	1.5	12	1.5	3	6.7	0	–	0	–
71 ≤ f ≤ 75	17	1.8	18	2.3	0	–	0	–	0	–
76 ≤ f ≤ 80	19	2.0	27	3.4	11	24.4	1	2.4	0	–
81 ≤ f ≤ 85	28	3.0	46	5.8	10	22.2	1	2.4	0	–
86 ≤ f ≤ 90	56	6.0	62	7.8	14	31.1	2	4.8	0	–
91 ≤ f ≤ 95	87	9.3	118	14.9	5	11.1	5	11.9	0	–
96 ≤ f ≤ 100	118	12.7	151	19.1	1	2.2	3	7.1	0	–
101 ≤ f ≤ 105	141	15.1	126	15.9	0	–	7	16.7	0	–
106 ≤ f ≤ 110	174	18.7	96	12.1	0	–	12	28.6	0	–
111 ≤ f ≤ 115	103	11.1	44	5.6	0	–	4	9.5	0	–
116 ≤ f ≤ 120	78	8.4	26	3.3	0	–	4	9.5	3	7.5
121 ≤ f ≤ 125	46	4.9	24	3.0	0	–	1	2.4	7	17.5
126 ≤ f ≤ 130	21	2.3	4	0.5	0	–	2	4.8	10	25.0
131 ≤ f ≤ 135	11	1.2	4	0.5	0	–	0	–	5	12.5
136 ≤ f ≤ 140	0	–	0	–	0	–	0	–	8	20.0
141 ≤ f ≤ 145	2	0.2	0	–	0	–	0	–	4	10.0
146 ≤ f ≤ 150	0	–	0	–	0	–	0	–	3	7.5
151 ≤ f ≤ 155	0	–	0	–	0	–	0	–	0	–
156 ≤ f ≤ 160	1	0.1	0	–	0	–	0	–	0	–
161 ≤ f	0	–	0	–	0	–	0	–	0	–
Sum.	932	100.0	792	100.0	45	100.0	42	100.0	40	100.0

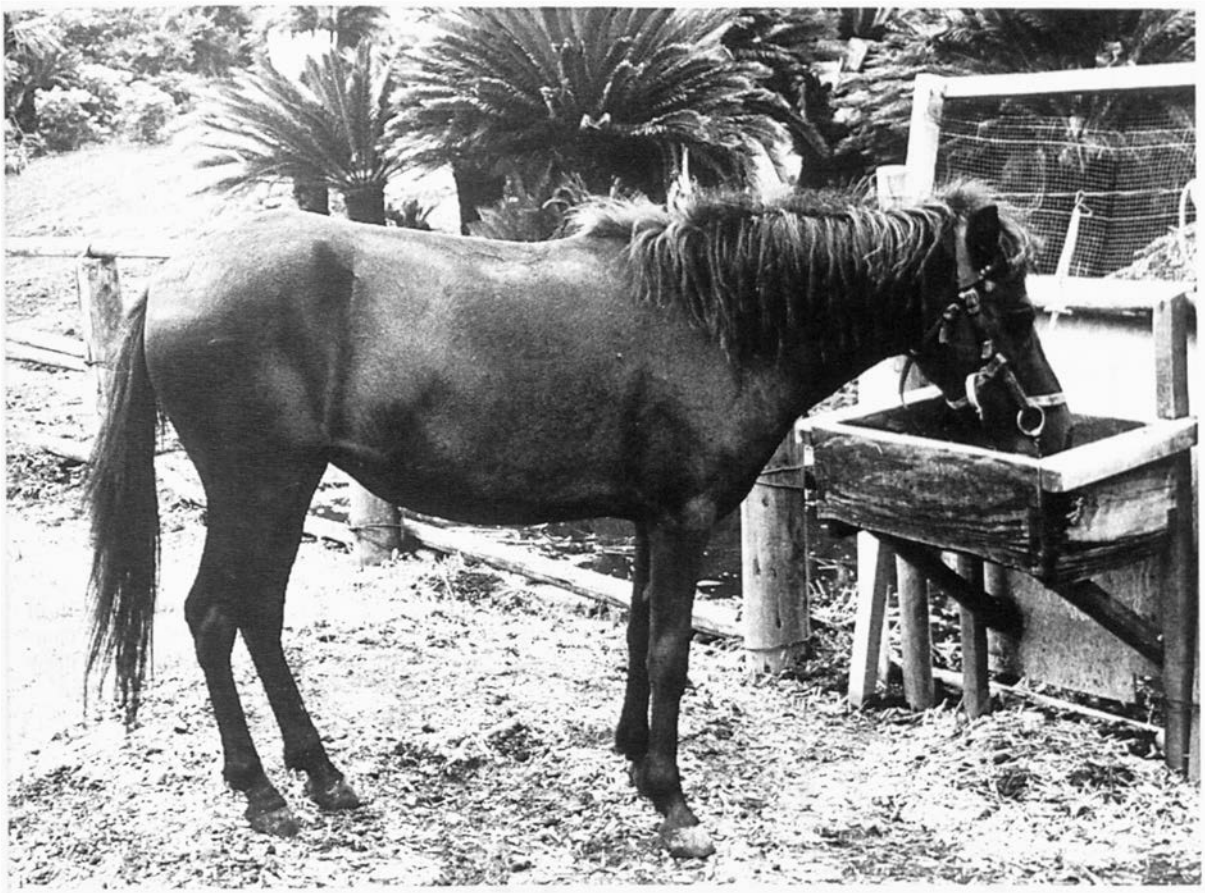

Fig. 8: The Tokara horse.

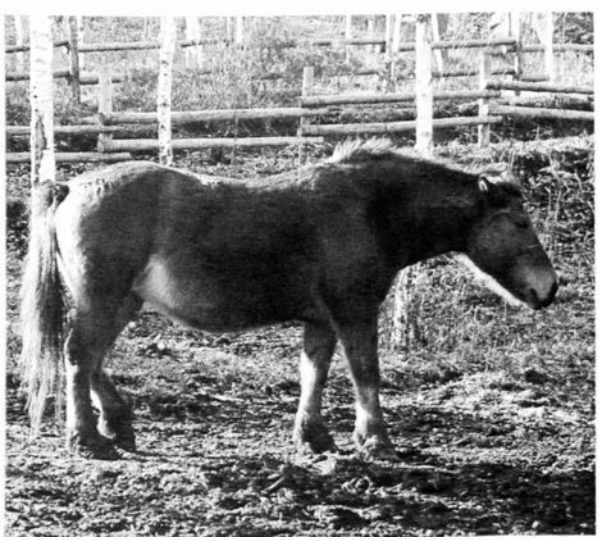

Fig. 9: The Kiso horse.

(2) Shape of outline.
The shapes of well preserved prints are closely similar to hoof prints of modern horses. Hoof prints' depths were from 0.5 cm to 1.5 cm.

(3) Discovery of horse's tracks.
We recognized several circle prints to be the same as those of modern horse walking tracks.

Conditions of estimating the withers height from hoof print

This estimation will not be realized without the next two conditions, namely the coincidence of hoof print with hoof in size, and the interrelationship between hoof size and horse withers height.

In this study, we selected the Tokara, the Kiso horse and Thoroughbred for comparison with the ancient horse from the Shiroi site. The Tokara horse lives in the south-

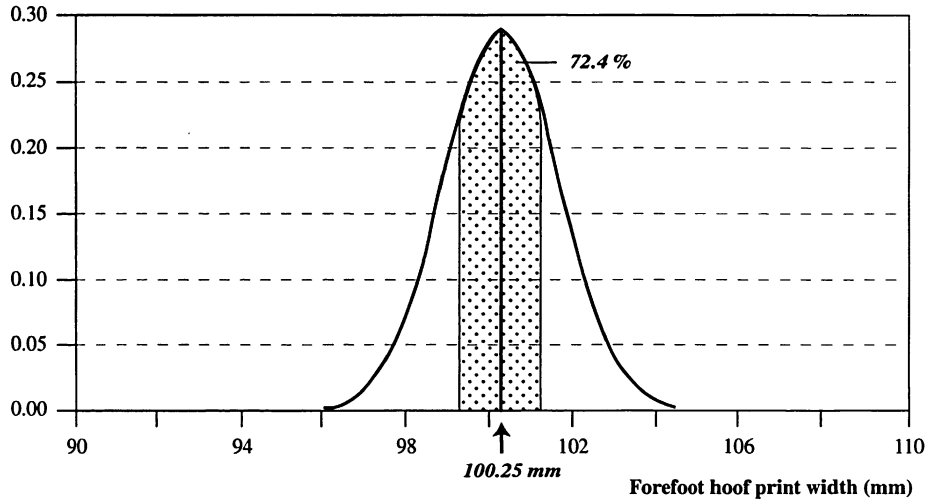

Fig. 10: The frequency distribution of forefoot hoof print width of a medium-type native horse (hoof width is 100 mm).

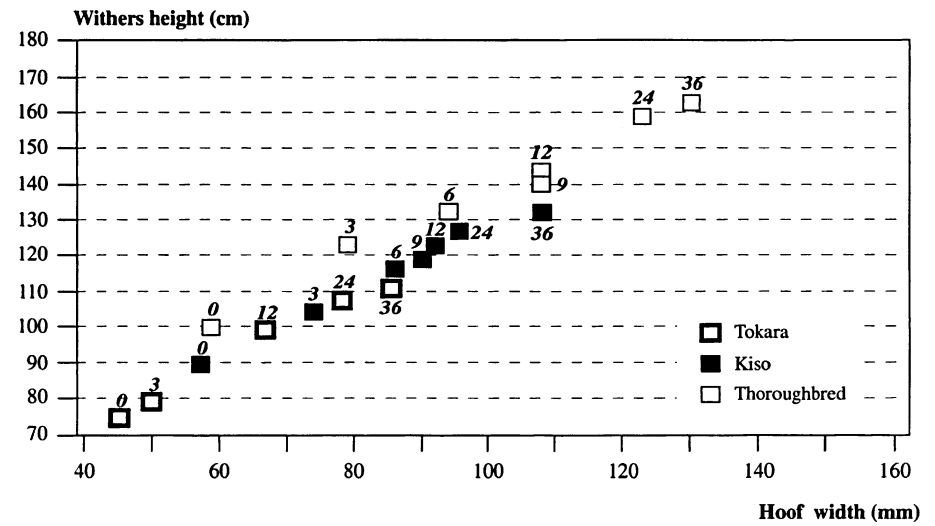

Fig. 11: The growth of Tokara, Kiso and Thoroughbred horses: withers height and hoof width.

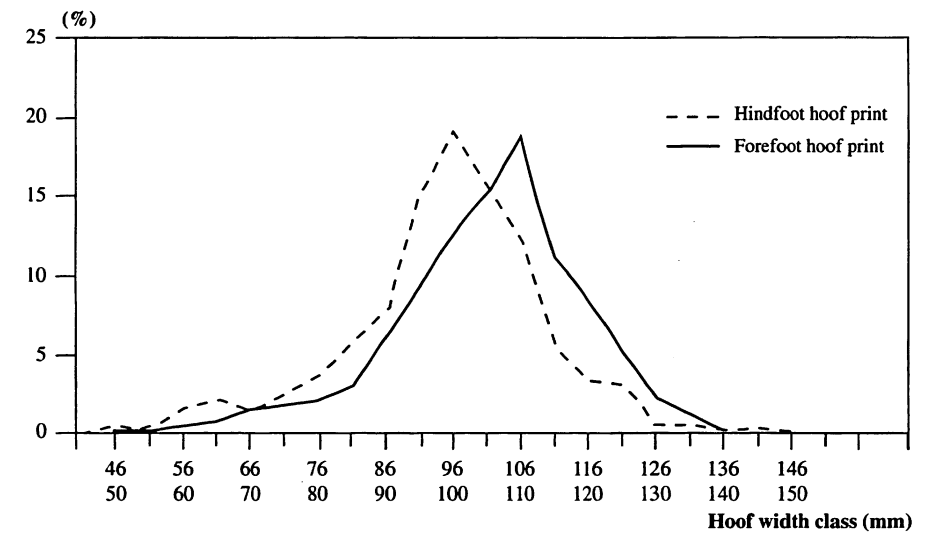

Fig. 12: The frequency distribution of forefoot hoof print width and hind hoof print width of the Shiroi horse.

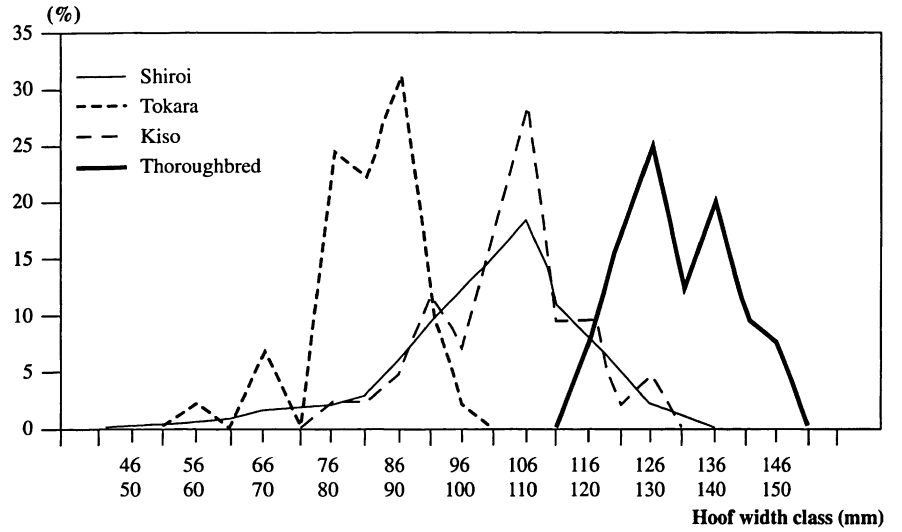

Fig. 13: Comparison of the Shiroi, Tokara, Kiso and Thoroughbred horses: hoof width.

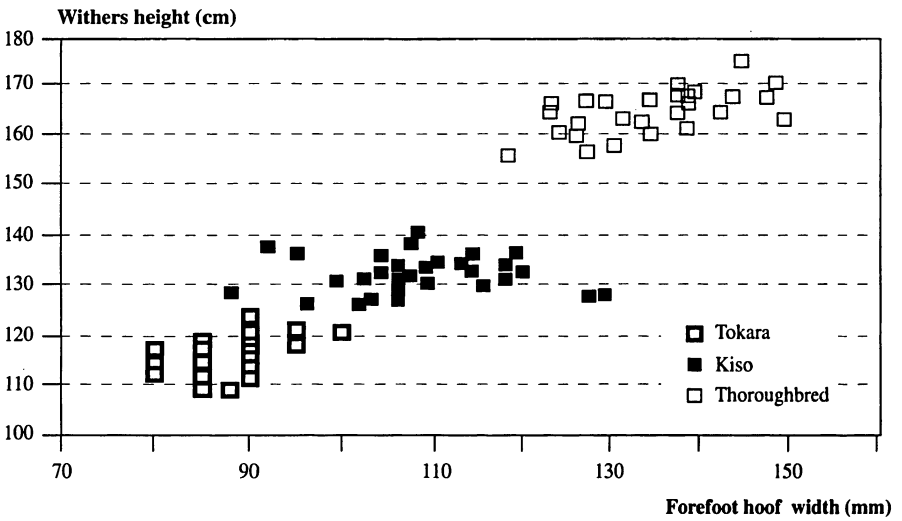

Fig. 14: Comparison of Tokara, Kiso and Thoroughbred horses: withers height and hoof width at maturity.

west Islands of Japan, and the full-grown average withers height is only about 115 cm, so it is assigned to the small horse category (fig. 8). The Kiso horse, which is classified as a medium-type horse, lives in Central Japan and the full-grown average withers height is about 130 cm (fig. 9).

We compared hoof width with the hoof print of a medium-type native horse whose hoof width is 100 mm without horseshoe, which resulted in showing that only a slight difference existed between them (fig. 10). 72.4% of hoof print widths are within the distribution range of ±1.5 mm from the average (100.25 mm).

There are only a few reports on the relationship of hoof width and horse withers height in Japan but they are roughly done. So we tried to examine as many modern horses as possible, that is: 40 Tokara horses, 3 Kiso horses and 40 Thoroughbreds, and then we analyzed our data and 42 Kiso horses' data measured by Dr. Tsujii (1984) and 5 foals of Thoroughbred's data measured by Mr. Osanai *et al.*, 1983.

Figure 11 shows hoof width and withers height from the foal to the full-grown horses. The horizontal line shows hoof width, the vertical line shows withers height. The

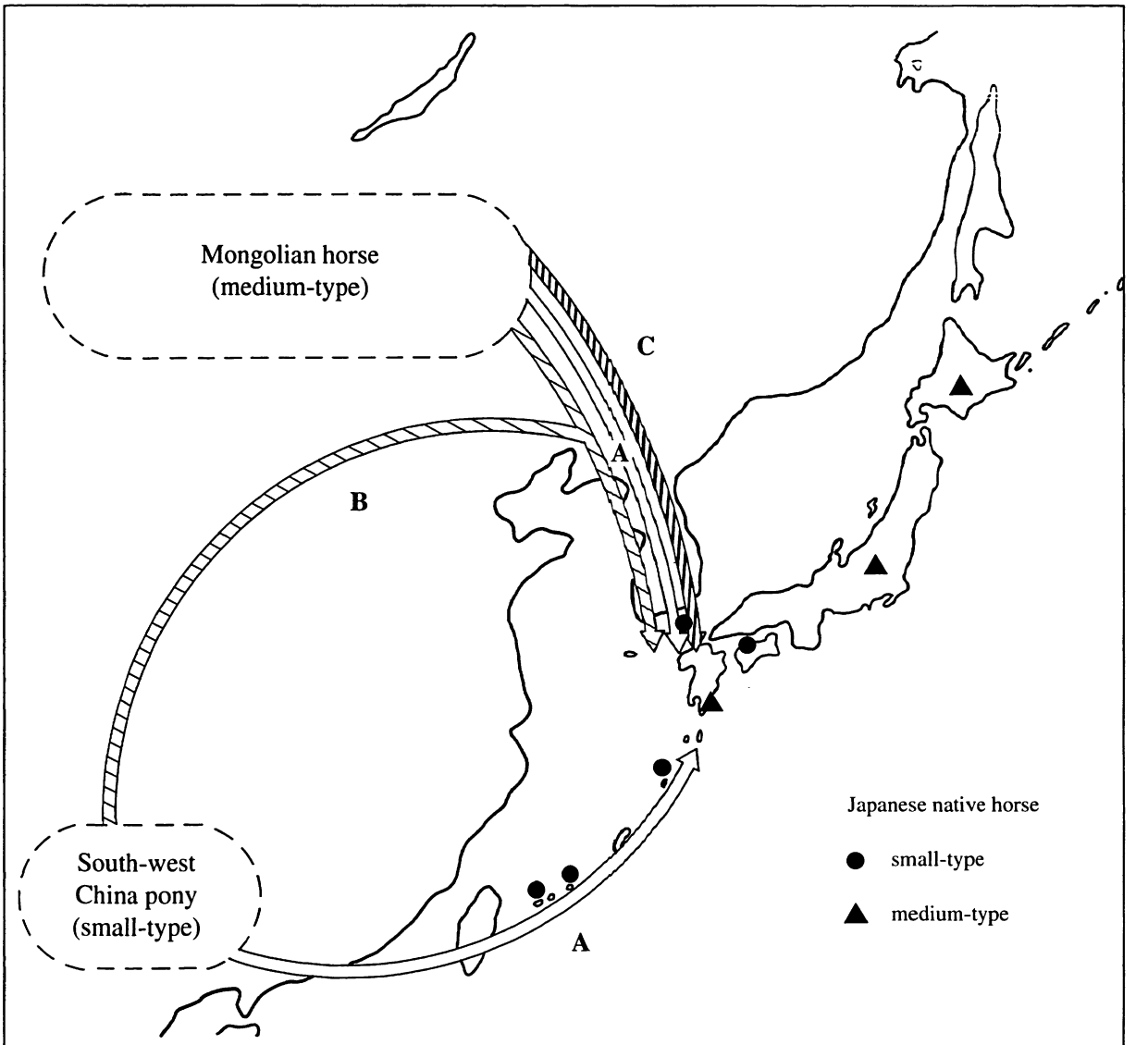

Fig. 15: The distribution map of the Japanese native horse and its route of entry from the Eurasian Continent.

numbers in the graph show horse age in months. A short withers height horse has small hoof width and a tall withers height horse has large hoof width. So we have come to the conclusion that the hoof width and withers height are closely interrelated.

By the way, we could not distinguish between mare and stallion from the hoof prints because there is not a large difference in shape and width of hoof prints between them.

Estimating the withers height of the Shiroi horse

The Shiroi horse is named for the Shiroi site where its hoof prints were found. We measured and recorded hoof prints widths, lengths and directions of approximately 2,300 good samples. We made a graph from 932 samples of forefoot hoof prints and 792 samples of hind hoof prints (fig. 12, tab. 1).

We chose the hoof print widths for estimating withers height from measured hoof print widths and the hoof print lengths at the Shiroi site. This is because the hoof print widths are more similar to hoof size than the hoof print lengths. That is due to the longitudinal sliding of the hoof, causing its print to be longer than its own length. But the hoof print's width is closely similar to the hoof width even if the horse hoof slides longitudinally, as lateral sliding is minimal.

Figure 12 is a frequency distribution that divides hoof prints width at 5 mm intervals. And the frequency of each class shows the ratio between number of prints in each class and all of hoof prints. The horizontal line shows class, the vertical line shows frequency.

Regarding the Shiroi horse's hoof print width of forefoot, the minimum size is 47 mm, the maximum size is 156 mm, the average size is 102.9 mm, and the most frequent class is from 106 mm to 110 mm. As for the hind hoof print width, the minimum size is 47 mm, the maximum size is 133 mm, the average size is 96.9 mm, and the most frequent class is from 96 mm to 100 mm. There is a difference between the forefoot hoof prints width and hind hoof prints width, because the forefoot hoof width is slightly wider than hind hoof width on any one horse.

Figure 13 shows the comparison between the hoof prints of the Shiroi horse with those of the Tokara horse, Kiso horse and Thoroughbred. The frequency distribution is the same as in figure 12. But the modern horse's sample is few in number and does not include data for horses under one year of age. We found that the distribution range and most frequent class of the Shiroi horse coincided with the Kiso horse.

However, there is a difference range between the Shiroi horse and the Kiso horse under 75 mm. But this range coincided with the hoof size of a Kiso horse under one year of age. It means that foals under one year of age were at the Shiroi site.

Figure 14 shows hoof width and withers height of the full-grown horses. The withers height of the Kiso horse is distributed from about 125 cm to 135 cm. Therefore, it is revealed that the Shiroi horse was the same medium-type horse as the Kiso horse and its withers height was about 125 cm to 135 cm.

In addition, we can also estimate from the step distance from the tracks that were found at the same site. We measured 19 samples of the steps. The steps are distributed from 63 cm to 90 cm and the average step distance is 76 cm. Estimating from these steps, the withers height of the Shiroi horse is 129.2 cm. This data is not contradictory to the estimation of withers height from hoof print.

By the way, S. Miyazaki (1993) compared the average of the hoof prints' width at the Shiroi site with the Kiso horses' data which were measured by Dr. Tsujii. He then came to the conclusion that the Shiroi horse was the same medium-type horse as the Kiso horse.

Conclusion

As a result, we can reach the conclusion that the horse from this site was a medium-type horse.

By the way, there are some theories about the route and time of entry and type of ancient Japanese horse, but it is still a controversial problem (fig. 15). Research on ancient horses in various parts of Japan may throw light on this difficult problem. But the area of Gunma Prefecture has not yielded ancient horse bone in the Kofun period that can be used for estimating withers height from the bone length. The Shiroi horse left only hoof prints at the Shiroi site, but they offered us very precious data for the Japanese ancient horse.

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