AGE ESTIMATE FOR THE MOUNDED TOMB OF HIMIKO BY SHAPE ANALYSIS

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ABSTRACT: In 2018, a large keyhole-shaped tomb mound was discovered in Tagawa, Japan. The field survey was carried out for this tomb using UAV. The length is 443m, the diameter is 152m, and the height is 33m: the second biggest mound in Japan. Next, shape analysis for the mounded tomb group in Tagawa was carried out from the sizes of the tombs. These ages were estimated as the 3rd century to the 4th century. On the other hand, Yamatai country existed in north Kyushu with the queen, Himiko in the late 3rd century. Those estimates corresponded to the Himiko era and following era.

1. INTRODUCTION

In the 3rd century in Japan, 30 countries were recognized by China. Yamatai country was a representative of them. However, the location of this country and Himiko's tomb was still uncertain. The fundamental reasons were Sanguozhi description: the location of 8 countries was shown by the directions, the distances, and family numbers. Most of historians judged the location of each country by only the directions and distances. Nobody used the family numbers for the location of each country. If the location of each country was calculated by three parameters: the directions, the distances and the family numbers, the result should be changed. The family numbers can be derived from the river watershed areas: the constant ratios of rice fields exist each river watershed and each family needs ten a. Therefore, the river watershed corresponded to a country. For the past 100 years, two areas were discussed between two major universities: Kyushu island and Kinki; the former was selected from the directions in Sanguozhi while the

latter was selected from the distances in it. RMS, Root Mean Square, is the indicator of optimization for Yamatai country location. On the other hand, in 2018, one big ancient tomb was discovered in Tagawa, Fukuoka: the length is 443 m, the diameter is 152 m, and the height is 33 m: the second biggest mound in Japan. The diameter of Himiko's tomb was described as 150 m in Sanguozhi, corresponding to this tomb.

2. METHODS

2.1 3D images

The 3D images for the tomb of Akamura were measured by UAV. UAV was Phantom 4 Professional with 4K camera. Pictures were synthesized to 3D orthogonal images with PhotoScan. The orthogonal image was processed to a monochromic silhouette and the edge image with Photoshop. Fractal analysis was carried out for these horizontal images and DEM. Fractal dimension D is defined as

$$D = \log N / \log R$$

where N is the number of pixels and R is the size of the images.
The shape factor ϕ is defined as

$$\phi = L^2 / S$$

where L is the maximum length of images and S is the area of the images.
Topographical rules were also applied for horizontal images and cross sections of DEM.

2.2 Dating the ancient tombs

By the list of the ancient tombs, two regression expressions were obtained for the dating of discovered tombs. The types of the tombs were three: keyhole, round, and ellipse shapes and the dates each was built. The keyhole type has three sizes, the diameter a, the base b, and the length c, which are correlated with the date. The round type has two sizes, the diameter D and the height H, which are correlated with the dates.

2.3 Location optimization of Yamatai

Each country has a family number, which correlated with the river watershed area. Each family has 10 a of a paddy field and the ratio of paddy fields was estimated as 1 to 5 % of each river watershed, 2.5 % on average.
RMS, Root Mean Square, was introduced as the indicator of optimization for Yamatai

country location.

$$\mathrm{RMS} = \sqrt{\left(\frac{DISa}{DISs} - 1\right)^2 + \left(\frac{DIRa}{DIRs} - 1\right)^2 + \left(\frac{FAMa}{FAMs} - 1\right)^2} \quad (1)$$

where *DISa*: the actual distance, *DISs*: the distance in Sanguozhi, *DIRa*: the actual direction, *DIRs*: the direction in Sanguozhi, *FAMa*: the actual family number, and *FAMs*: the family number in Sanguozhi.

3. RESULTS

3.1 3D images

The dimensions of Akamura tomb in Tagawa were bigger than Hashihaka tomb in Kinki. The former dimensions were the maximum length: 443 m; the circle diameter: 152 m; the height: 22 m; the bottom side: 230 m; the maximum height: 33 m. the latter dimensions were 278 m, 150 m, 30 m, 130 m, and 30 m, respectively.
The fractal dimensions were 1.859 for the silhouette for 1.249 for the edge.

3.2 Dating the ancient tombs

The regression line of keyhole shape tombs was next equation (N=38).

$$\mathrm{Year} = 296.12 \cdot \mathrm{b/c}\ (r^2 = 0.3049) \quad (2)$$

where b is a square size and c is a total length (see Figs.2,3, and 4).
The regression line of round barrows was next equation (N=85).

$$\mathrm{Year} = 59.57 \cdot \mathrm{H/D} + 454.13 (r^2 = 0.2463) \quad (3)$$

where H is the height of the tomb and D is the diameter of the tomb (see Figs 5 and 6).
Therefore, Akamura keyhole tomb was estimated to be constructed as 399AD, while Onzuka was estimated as 307AD with an error of 30 years.
Therefore, these tombs might be constructed in the late 3rd to the 4th century, which corresponded to the Himiko era, late the 3rd century.

3.3 Location optimization of Yamatai

According to a list of rivers, watershed area and sites are shown in Table 1. From the watershed areas, family numbers were calculated each. Finally, the results were

obtained as in Table 2. Yamatai country was estimated as the Chikugo river watershed.

4. DISCUSSION

4.1 Two locations of candidates for Yamatai

Most of historians estimated Yamatai country would exist at Kyushu and Kinki: the former should be the Chikugo river watershed, while the latter should be Yamato river watershed. These location estimates used the direction and distance from Seoul in Korea described in Sanguozhi. In this paper, the location estimate used the direction, distance and family number with RMS. No historians recognized the family number depended on the river watershed areas. The paddy fields distributed at a certain ratio of the total river watershed areas, 1 to 5 % of the total. Finally, the optimum ratio was 1.94%. Most of the countries in Japan constitute of river watersheds, therefore, the countries in the 3rd century in Yamatai alliance should be also river watersheds each.

4.2 Himiko's tomb

Sanguozhi described Himiko's tomb had a diameter of 150 m. This statement suggested Himiko's tomb would be a round tomb. However, most historians and archeologists supported Hashihaka tomb in the Yamato river watershed. This type was a keyhole tomb. In Tagawa many tombs were a round type. Therefore, true Himiko's tomb should be a round type. Onga tomb was a round type with a diameter of 150 m, corresponding to Sanguozhi description.

5. CONCLUSIONS

The authors concluded as next.

(1) Fractal analysis showed the same values of fractal dimensions between Akamura tomb and Nintoku Emperor tomb.
(2) Two gigantic tombs in Tagawa were estimated in 307 to 399 year AD with an error of 30 years, corresponding to Himiko's tomb year. Both tomb diameters were 152 to 264 m, corresponding to Sanguozhi description.
(3) Three parameters in Sanguozhi, the direction, distance, and family number, determined Yamatai country location the Chikugo river watershed, and rejected the Yamato river watershed with the optimization of the location. Therefore, Hashihaka's tomb was also rejected as Himiko's tomb that most historians

supported.

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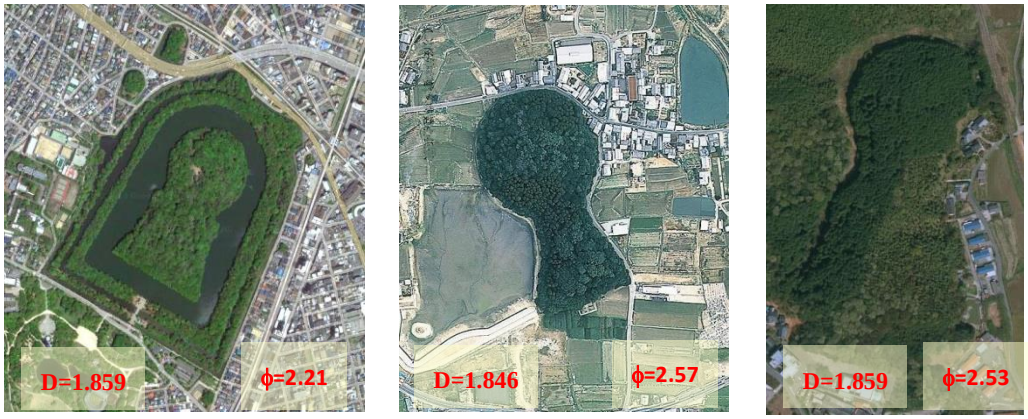

Figure 1 Three tombs: Nintoku, Hashihaka and Akamura

Table 1 List of Kyushu rivers

River	Watershed area km^2	Family number
Onga	1026	25650
Chikugo	2860	71500
Matsuura	341	8525
Rokkaku	341	8525
Honmyo	249	6225
Kikuchi	996	24900
Sirakawa	480	12000

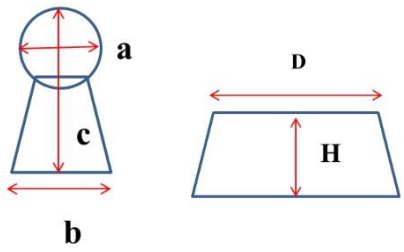

Figure 2 Keyhole and round tomb sizes

Midori	1213	30325
Kuma	1880	47000
Yamakuni	540	13500
Ohno	1465	36625
Ohita	650	16250
Gokase	1820	45500
Omaru	474	11850
Ohyodo	2230	55750
Sendai	1573	39325
Kimotsuki	485	12125
Bansho	464	11600

Table 2 List of Kinki rivers

River	Watershed area km^2	Family number
Enokawa	3900	97500
Yoshino	3750	93750
Takahashi	2670	66750
Shingu	2360	59000
Watari	2270	56750
Hii	2070	51750
Yoshii	2060	51500
Yura	1880	47000
Kinokawa	1660	41500
Ohta	1700	42500
Niyodo	1560	39000
Yamato	1080	27000

Table 3 List of RSM for countries

Country	Continuous	Radiated	Kinki
Ito	Zuibaiji	Zuibaiji	Zuibaiji
Nu	Hakata	Hakata	Hakata
Fumi	Hanazuru	Shika	Shika
Toma	Onga	Kuma	Hii
Yamatai	Chikugo	Chikugo	Yamato
RMS	0.9241	0.6050	1.5552

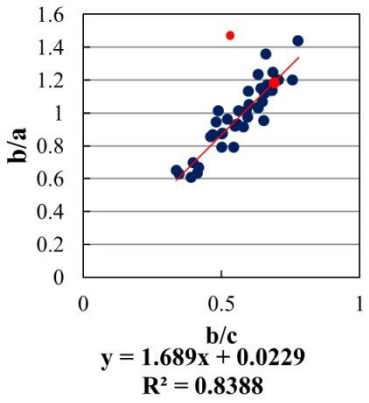

Figure 3 Keyhole tomb size correlation

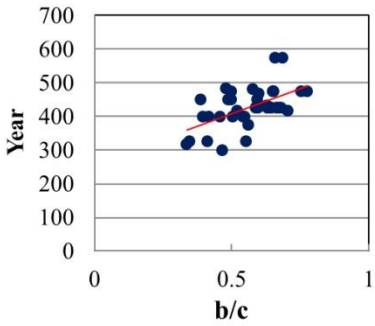

Figure 4 Keyhole tomb age estimate

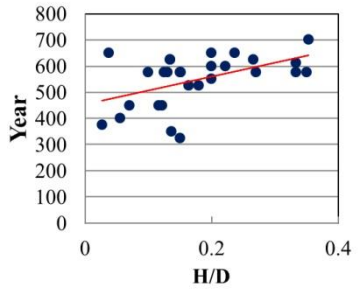

Figure 5 Round tomb age estimate

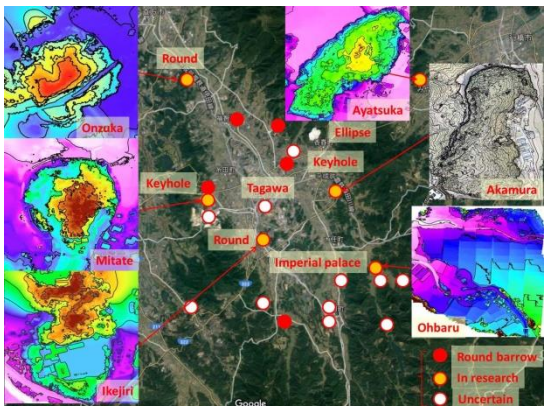

Figure 6 Spatial distribution of tombs in Tagawa

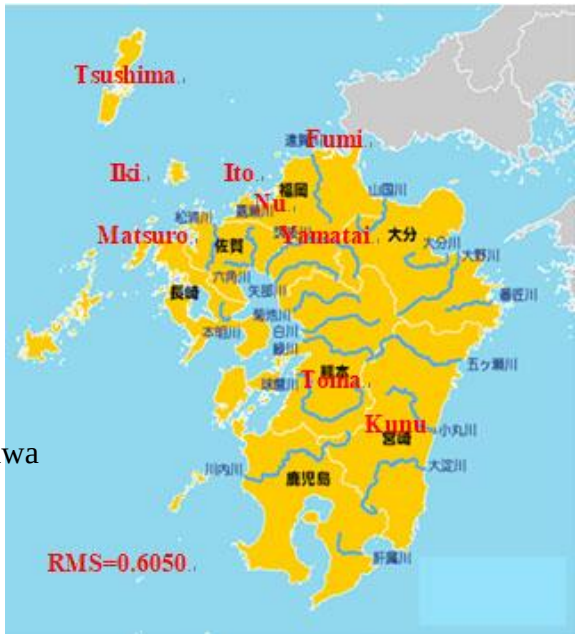

Figure 7 Optimized Yamatai countries (Radiated theory)

Figure 8 Optimized Yamatai countries (Continuous theory)

Figure 9 Optimized Yamatai countries (Kinki theory)

Appendix 1 Analysis of morphology for keyhole-shaped tombs

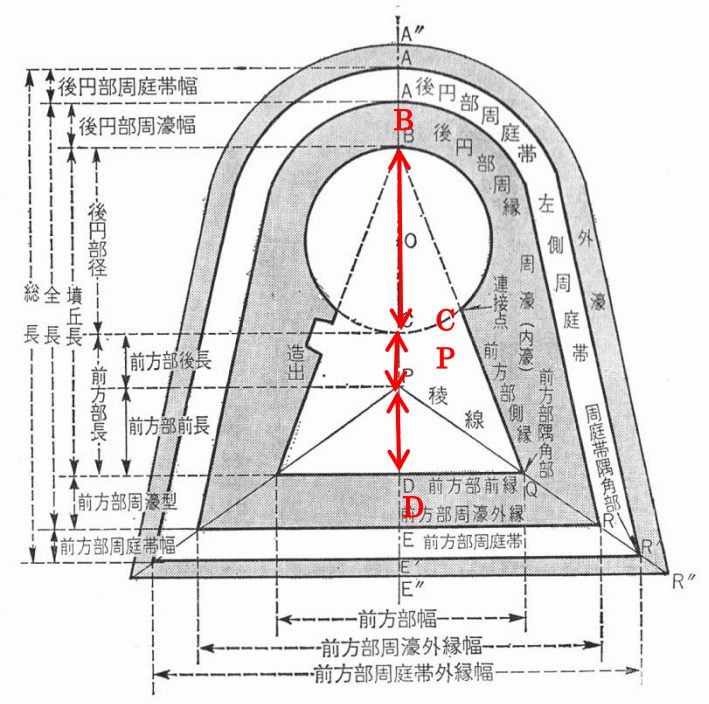

Figure 10 Morphology of keyhole-shaped tombs

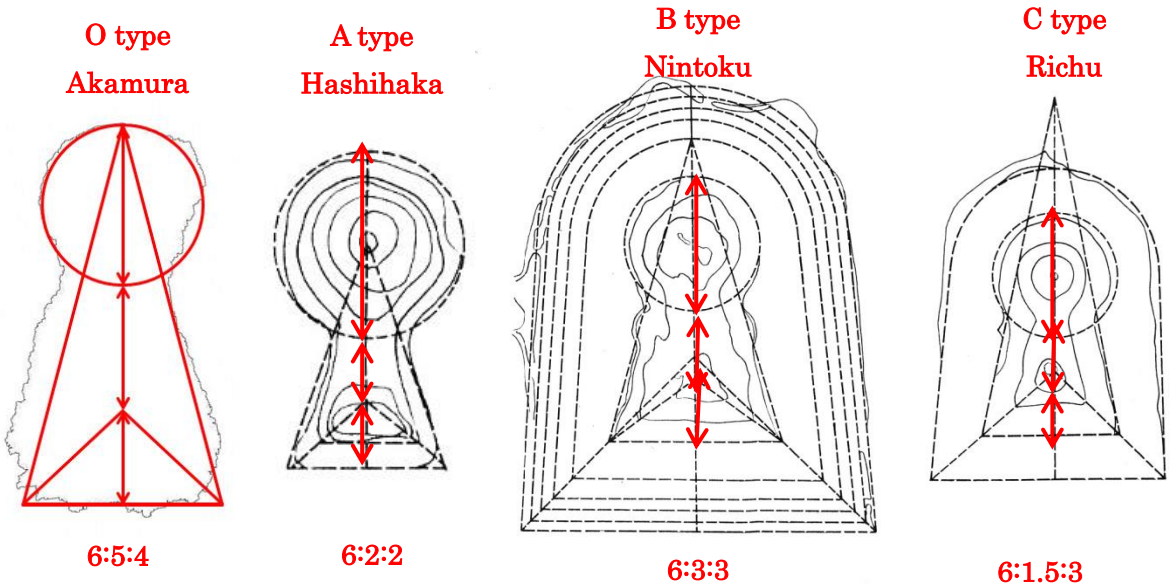

Figure 11 Four types of mounded tombs by Ueda classification(1969)