

# Experimental practice using 3D scanning for understanding the structure of a stone chamber from the Kofun period, Japan – A case study of the Shobuzako Kofun, Okayama prefecture –

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## Resumen

*El Shobuzaku Kofun, localizado en la prefectura de Okayama (Japón occidental), es una tumba con forma de “ojo de cerradura” construido sobre un montículo natural y está fechada en el siglo V d.c. Su cámara funeraria de piedra y artefactos asociados están en muy buena condición dado que la cámara no ha sido saqueada.*

*En esta presentación, nosotros presentaremos un caso experimental del uso de técnicas de medida en 3D para registrar y entender la estructura de una cámara funeraria de piedra, así como la distribución de objetos asociados a la tumba en el Shobuzaku Kofun. Presentaremos algunos de los beneficios y problemas de las técnicas de medida en 3D, y las observaciones principales al usar este método.*

**Palabras Clave:** KOFUN, ESTRUCTURA DE LA CAMARA DE PIEDRA, CONTEXTO FUNERARIO, MEDIDAS EN ESCANEEO 3D

## Abstract

*The Shobuzako Kofun, located in Okayama prefecture (western Japan), is a key-hole tomb set on a low rolling hill dating to the 5<sup>th</sup> century AD. Its stone chamber and burial goods are in very good condition because the stone chamber has not been looted.*

*In this presentation, we will indicate a case study of the experimental use of 3D measuring techniques for recording and understanding the structure of a stone chamber, as well as the layout of burial goods' layers in the Shobuzako Kofun. We will show some of the benefits and problems of 3D measuring techniques, and the basic remarks for using this method.*

**Key words:** KOFUN, STRUCTURE OF STONE CHAMBER, BURIAL CONTEXT, 3D SCANNING MEASUREMENT

## 1. Introduction

Since 1998, the Department of Archaeology of Okayama University has surveyed and excavated several burial mounds (Kofun in Japanese) dating from the late 5<sup>th</sup> century to the early 6<sup>th</sup> century A.D. in order to understand the dynamics of the history of the so called ‘Yuryak dynasty period’ in Kibi region (roughly Okayama prefecture in the present). We have finished excavations of Tenguyama Kofun (late 5<sup>th</sup> century) and Nima-Otsuka Kofun (early 6<sup>th</sup> century) until now, and we excavated Shobuzako Kofun from 2001 to 2008 (fig.1). Shobuzako Kofun is a key-hole shaped mound measuring 42m in length, and it has a vertical stone chamber. In the 2007 season, human bones and rich burial goods were found in the unlooted stone chamber inside the burial mound (fig.2). Thereby, it became clear that Shobuzako Kofun dated for the late 5<sup>th</sup> century. When we excavated this stone chamber, we carried out 3D measurements (along with Seibu technological consultant Co. Ltd.) for understanding, in three-dimension, the structure of the stone chamber and the context of burial goods.

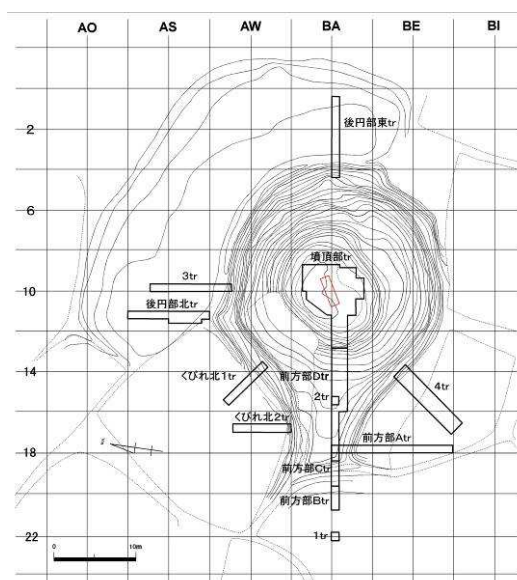


Figure 1. Contour of the Shobuzako Kofun.



Figure 2. Interior of the stone chamber.

In late years of Japanese archaeology, 3D measuring techniques are used as a new method of observation, recording and investigation. Their use is well established for archaeological artifacts, especially bronze mirrors and other objects (Archaeological Institute of Kashihara, Nara Prefecture, 2005), but it has not been yet fully used for archaeological structures. However there are few cases of 3D measurements in the surface of a mound (e.g. NIIRO, 2008) and stone chambers on passage-grave mounds from the 6<sup>th</sup> century (e.g. SEIKE, 2006). Measuring in 3D a vertical stone chamber and the layout of burial goods and its layers is almost a maiden attempt. In this paper we will show its results and some of the benefits and problems of 3D measuring techniques, as well as the basic remarks for using this method.

## 2. Shobuzako Kofun

Shobuzako Kofun is situated on a flat hillock ridge at an altitude of 26m above the sea level, at the lower reach of the Oda River, which flows into the Takahashi River in Mabi area near Kurashiki city, Okayama prefecture, Japan.

The burial mound is a key-hole shaped mound measuring 42m long (with 29m constituting the round part) and 7.5m high, surrounded by a moat. The square part is orientated to the direction of a mountain (orientation W-NW) and the round part is orientated to the direction of the head of a hillock ridge (E-SE).

The vertical stone chamber inside the burial mound is located 4m from the top of the mound and is 3.6m long, 1.2m wide and 0.6m high. The interior walls were built with worked stones and clay placed between the spaces, finishing them with plaster to level the wall. The floor was covered with round pebbles before placing the wooden coffin. This coffin itself has decayed, but three sets of iron cramps located in opposite positions along the wall were found. The interior wall is composed of square granite block and the floor is composed of rounded river gravel (Bessho and Matsugi 2008). Ceiling stones are divided in 8 parts, and all of them are sprinkled with red pigment. The stone chamber is packed with ash-gray clay.

The burial mound consists of an artificial lower reddish-brown stratum and an upper yellowish-white stratum.

Usually, the stone chamber is constructed after the burial mound, but in the case of Shobuzako Kofun, the burial mound is constructed after the stone chamber is built and funeral rites happened.

In the unlooted stone chamber, it was found a set of armory in almost perfect shape together with additional grave goods and the skull of the individual buried there. There is a part of the stone chamber that is not filled with debris. Therefore, this space is preserved as the original burial moment, something quite rare for these cases.

Skull bones were found resting on a bronze mirror. The rest of the grave goods were concentrated in the western half of the chamber. At the middle of the chamber, at least two bundles of iron arrowheads, two swords (accompanied with some wooden material), two whetstones, and a pair of small sized pottery were found. Further west, a suit of iron armor, a set of horse trappings, third bundles of arrowheads and two spearheads, along with other objects, were found.

As the result from a typological and assemblage study of these burial goods, it became clear that the Shobuzako Kofun was constructed in late 5<sup>th</sup> century and, since the process of constructing the burial mound and the rich use of clay in the stone chamber both originate in the southern Korean Peninsula, it shows a clear evidence of connections and influence from there.

## 3. 3D measurements

As written above, in the 2007 season we have carried out tentatively 3D measurements of the stone chamber and the burial context for a more detailed investigation. To improve our work efficiency, we have recorded the stone chamber by hand drawing in parallel with 3D measurements. The 3D measurements were carried out three times: first, when stone chamber was found (exterior stone chamber); second, when the burial goods have been found (burial context); and third, when the contents were recovered (interior stone chamber).

Equipment and materials were the Trimble GX 3D Scanner and the Konica Minolta VIVID9i, which are a non-contact 3D digitizer. The former gets the positional information in a coordinate system and color information, but it is not too capable of extraordinary precision. The latter is capable of extraordinary precision, but has no coordinate system. We have measured the area of excavation using the Trimble GX 3D Scanner, and the interior stone chamber and burial context using the Konica Minolta VIVID9i since it was necessary to measure with a high degree of accuracy. After measurements, latter data was integrated with former data.

At first, when the stone chamber was found, we measured the area of excavation using the Trimble GX 3D Scanner and the exterior stone chamber using Konica Minolta VIVID9i. Second, we measured the burial context using both equipments. Third, we measured the interior stone chamber using Konica Minolta VIVID9i. All these measurements show accuracy and made good use of time (Fig.3).

Equipments	GX	VIVID9i
First < exterior stone chamber >		
Objects	excavation area	ceiling stones
Accuracy	about 5mm pitch	30,000 points / 100cm <sup>2</sup>
No. of shots	6 times	106 times
No. of operators	2 people	3 people
Second < burial context >		
Objects	interior stone chamber	interior stone chamber remains
Accuracy	about 5mm pitch	30,000 points / 100cm <sup>2</sup>
No. of shots	4 times	107 times
No. of operators	2 people	3 people x 2 days
Third < interior stone chamber >		
Objects		floor of the stone chamber
Accuracy		12,000 points/ 100cm <sup>2</sup>
No. of shots		345 times
No. of operators		3 people x 2 teams x 2 days

Figure 3. Accuracy and No. of operators

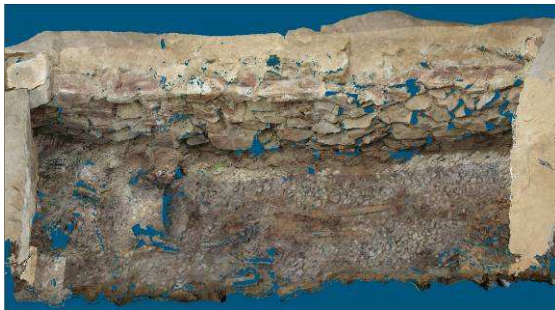


Figure 4. Some "blank data" of the stone chamber

After the measurements took place, we used a design software for three dimensional data (Real Works Survey and Rapid form) and created the archaeological drawings, plan, section and contour drawings of the stone chamber. We consider that the accuracy of measurement data shows no problems as archaeological data but, as Fig.4 shows, there is some "blank data" that can be observed. This "blank" appears because of a lack of data and, perhaps, because of a blind corner from measurement equipment. In the floor of the stone chamber irregularity is observed; this is perhaps caused by a trace of the wooden coffin (Fig.5). This figure is very useful because it is very difficult to show this irregularity by conventional methods. In addition, we integrated the 3D data of clay draping the stone chamber measured at about 3cm pitch using a Trimble S6 Total station (about 4,800 points) with the stone chamber data (Fig.6). This data may be perfunctory against the data of the stone chamber and burial context, but we consider that the accuracy of the data causes no problem for analyzing the form and irregularity of the clay draping the stone chamber.

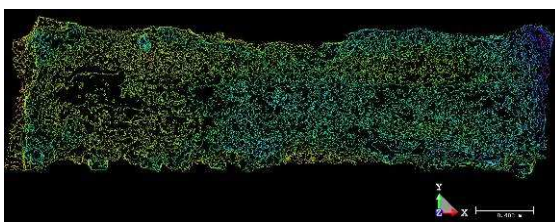


Figure 5. Contour of the floor.



Figure 6. Clay draping the stone chamber and the ceiling stones

#### 4. Concluding Remarks

By this experiment of 3D measurements of the stone chamber and the burial context in Shobuzako Kofun, we got a high-quality 3D data and archaeological hand-drawings, and we were able to know and record the work time abridge. Moreover, by doing these measurements several times, we were able to gather more accurate data, something that has not been done so far in Japan (Fig.7).

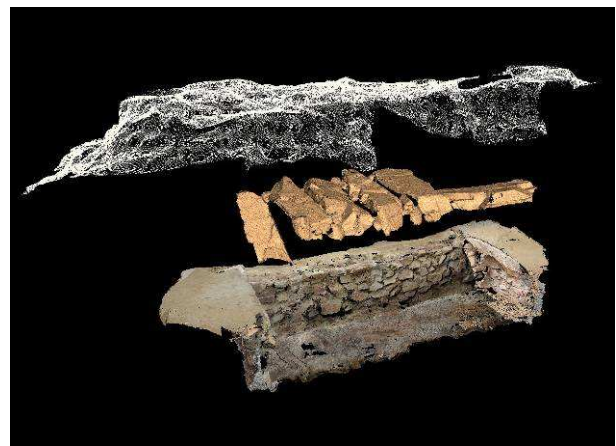


Figure 7. Structure of the stone chamber

However, there are also some issues. First, although we are satisfied with the speed and accuracy of 3D measurements, as well as its high-quality, it takes quite an amount of time to process the data after gathering, and also technical knowledge is needed. Second, since 3D measurements are mechanical (like taking a picture), interpretation of the data cannot be done while gathering it, therefore this data is difficult to use as usual 'archaeological drawings'. To overcome this issue, we have also carried out conventional hand-drawing in parallel with 3D measurement. This "mechanical" characteristic of 3D measurements is something that can not be overcome by nowadays software, with the risk of losing important

information about the interpretation of the archaeological context; because of this, we consider it is absolutely necessary to use conventional hand-drawing with these measurements. Also, for an archaeological structure, it is advisable to measure it several times in order to get accurate structural data, because measuring it only one time gives us just mere surface data. We need to mention that although we would have liked to carry out 3D measurements of the artifact superposition while excavation, because of time schedule, we were not able to achieve it in less than the excavation term.

Finally, although these are many issues to consider when using 3D measurements, we believe that this kind of technique was very useful as a methodology of recording data since the excavation process destructs the context. It is also another challenge to seek applications for this methodology, as well as to use it in other cases, so the methodology itself can develop more as well as its applications.

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