Variation of Paleotopography around the Ssangsujeong Pavilion Area in Gongsanseong Fortress using GIS and 3D Geospatial Information

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ABSTRACT Gongsanseong Fortress was registered as a World Heritage Site in 2015 as a representative cultural heritage from the Woongjin Baekje period, and it has been used throughout the entire period from Baekje Kingdom to the Joseon Dynasty. Within Gongsanseong Fortress, the area around Ssangsujeong is presumed the site of royal palace of the Woongjin Baekje. Also, the excavated culture layers of the Baekje Kingdom, the Unified Silla period, and the Joseon Dynasty were confirmed. In this study, paleotopography was modeled by digitally converting the elevation data obtained through surveying the excavation process, and the use of the topography in the Ssangsujeong area was considered by examining the variations in the topography according to the periods. As a result, the topography of the slope around the peak changed by periods, and the topography did not change on the flat land. The topography between the Baekje Kingdom and the Unified Silla period appeared to be almost identical, and it seems that the space of the Baekje period was maintained as it is. Also, during the Joseon Dynasty, it is confirmed that flat surfaces in the previous period were used. However, sediments on the slopes flowed down, reducing the area of the flatland, and architectural techniques that could utilize the natural topography of the changed slope were applied to interpret it as having a different topography from the previous period. In order to model and interpret the paleotopography, excavation data, geological and topographic analysis, and digital data must be secured. It is expected that location conditions and ancient human life can be identified if the analysis technique in the study is applied to other archaeological sites in the future.

Key Words Gongsanseong, Paleotopography, Geographic information system, Topography modeling, Geostatistical analysis

1. INTRODUCTION

The topography is the shape of the earth’s surface formed by the elevation, slope and curvature, and is changed by internal and external factors. Internal factors influence macroscopic topographical changes, and external factors dominate the formation of detailed topography. The internal factors are changes caused by the radioisotope decay energy inside the earth and include orogeny, volcanic activity, and subsidence or uplift of the crust. The external factors include the daily motion of sun, wind, rain, stream flow, and waves, which cause erosion, transportation, and sedimentation. The resistance to erosion depends on the type of rock or metamorphism, which develops into various topography types by differential erosion.

The current topography is the final result of various factors, and it is difficult to know what process the topography went through. Therefore, to indirectly confirm the change in topography, it is necessary to analyze the sedimentary layer and structure observed in the cross-section of the soil layer. The soil texture of the sedimentary layer depends on the maturity level, and the sedimentary structure indicates the environment at the time.

This analysis method is based on modern stratigraphy, and the vertical relationship of sedimentary layers is interpreted as a result of horizontal sedimentation (Walther, 1894). Through the analysis of the sedimentary environment, some environmental changes can be inferred from hundreds to hundreds of thousands of years. Also, age dating technique has recently been applied to identify the topographical
changes in the historical era (Kim et al., 2016).

However, to check the cross-section of soil layer, trenches or drilling are required, and applying it to the site having cultural heritage is not simple task. Therefore, in analyzing the topography of cultural heritage, the topographic change is traced in reverse by synthesizing data such as old maps, ancient documents, archaeological excavation data, cadastral and topographic maps after the Japanese colonial era. Various software capable of analyzing geographic information has recently been developed, and Two-dimensional (2D) and Three-dimensional (3D) modeling of paleotopography can be performed with these technologies. In addition, it is possible to check the topography change according to the times and analyze the site conditions of cultural heritage (Heo, 2020; Lee and Heo, 2021).

This study investigates the topographical changes around the Ssangsujeong Pavilion area in Gongsanseong Fortress by synthesizing geographic information on the current topography. For information on the topography of the Baekje Kingdom, Unified Silla, and Joseon Dynasty, cadastral survey data performed during the excavation process were used. Cadastral survey data were prepared as contour maps by applying geostatistical techniques and were processed into digital elevation model or triangulated irregular network model using GIS analysis software. Finally, the topographical changes around the study area were reviewed by synthesizing the paleotopography modeling results.

2. METHODOLOGY

2.1. Geography and geological setting

The Baekje Kingdom is an ancient country located in the southwestern part of the Korean peninsula, and the period is divided according to the location of the capital city. The second capital of the Baekje Kingdom was Gongju (Woongjin) from 475 to 538, and Gongsanseong Fortress was...
registered as a World Cultural Heritage Site in 2015 as representing the Woongjin Baekje period. The location of the royal palace during the Woongjin Baekje period has not been identified.

When synthesizing archaeological research data, it is presumed that the royal palace site may be located inside Gongsanseong Fortress or in the downtown area of Gongju (Seo, 2001; Lee, 2001). The wide flat area is located around the Ssangsujeong Pavilion inside Gongsanseong Fortress, and small scale pond and building sites were discovered through excavation, confirming its potential as a presumed royal palace site (Ahn and Lee, 1987).

Gongsanseong Fortress surrounds Mt. Gongsan with an altitude of 110 m and small peaks around it, and the Geumgang river flows to the north, making it a favorable terrain for defense against enemies. The main valley is developed in the north direction of the fortress, and a vast flat land has been created to centered on the lowland at the bottom of the valley, and various types of building sites are located (Figure 1A).

Most of the highlands near the peak are composed of slopes, and the flat land in the Ssangsujeong area is the only one except for the narrow space in the Imryugak building area. Ssangsujeong is located on the southwestern peak of Gongsanseong Fortress, with a flat land of over 10,000 m² centered on the high peak. Jinnamru, which corresponds to the south gate of Gongsanseong Fortress, exists to the southeast of Ssangsujeong and is surrounded by steep slopes except for the entrance to the east of Ssangsujeong (Figure 1B, 1C, 1D).

The formation of topography has a high correlation with the distribution of geology and soil in the area, and the rock and geological status of the Gongsanseong Fortress have been reported by Kim et al. (1976) and Lee and Jo (2012). As geological map, a diverse rock species distributed widely in Gongju such as metamorphic rocks of the Precambrian, gneissic granite and biotite granite of unknown age, andesites of the Cretaceous, and sedimentary rocks composing the Gyeongsang Supergroup. Among them, Gongsanseong Fortress is located in the Precambrian migmatitic gneiss, and small-scale intermediate and acidic dikes that penetrated it are observed in Gongsanjeong and Yeongeunsu temple. The area of the Ssangsujeong is composed of migmatitic gneiss never intruded by any dikes. Meanwhile, soils composed the underground of Ssangsujeong have sandy topsoil and loamy subsoil, so it is possible to have excellent water and air permeability characteristics due to the overall high ratio of sand.

2.2. Analytical method

The term of ‘geographic information’ has mainly meant data on topography, features, geographical names, and regional boundaries but recently, it concludes wide information including various types of geographic spatial coordinates directly or indirectly. In addition, to the cadastral survey data obtained directly from the field, remote sensing data obtained through aircraft or satellites are used together with the data for analyzing geographic information.

Each constant is used as it is stands or converted by the purpose of deriving the results desired by the user. During this process, the resolution of the results correlates with the amount and density of data, and overlapping, separating, and schematizing each data can interpret the association between the information (Estes et al., 1987).

In the study, the numerical information on the current topography and elevation information acquired during the excavation process was analyzed in order to confirm the topographical changes in the Ssangsujeong area by the period. For information on the current topography, a 1:1,000 scale numerical topographic map was produced through precise surveying of the Gongsanseong area. The coarse curve of 0.25 m, the minimum unit of contour lines, was used as the standard.

Geographic information uses a different coordinate system depending on how the shape of the geoid ellipsoid is defined, and the GRS80 ellipsoid adopted as a standard by the Korea National Geographic Information Institute was used. The coordinate system proposed by the European Petroleum Survey Group was used for the detailed location of the ellipsoid. Considering the location of Gongju, it was projected on the TM central origin coordinate system (EPSG 5186) based on the coordinates at 127° East Longitude and 38° North Latitude.

In order to estimate the surface of the Baekje, Unified Silla, and Joseon, survey and 3D scanning data at the time of excavation were reviewed. The cadastral survey data are elevation data measured using a light wave machine, and the elevation of the cornerstones and excavated culture layers of
the building site according to the period is recorded. These data were marked as points on a 2D floor plan printed on paper, the elevation value was recorded manually, and the conversion process into digital data was performed for geographic information analysis. In addition, to verify the reliability of surveyed data, the size and tendency of deviation were confirmed by comparing the elevation values for the same point of the 3D scanning data and the survey data at the time of excavation.

Elevation values by period present in XYZ coordination system and the elevation between each points is empty. Thus, geostatistical techniques such as interpolation should be applied to infer the elevation value between points. This study applied Kriging interpolation as an interpolation model to prepare a contour map. The topographic changes from the Baekje period to the present were reviewed through topographic analysis such as slope direction and aspect.

A digital elevation model for each period was produced using the prepared contour map. Finally, the sedimentation and human reclamation activities which caused these changes in the terrain were examined, and how the spatial utilization of the Ssangsujong area changed by the period was examined.

For these analysis, application program Surfer produced by Golden software was used to produce contour plots using historical elevation values, and AutoCAD (Autodesk) was used for the digital conversion of contour plots and elevation values. ArcGIS (ESRI) was used for terrain analysis and 2D modeling of converted digital data, and Sketch Up (Trimble) was used for 3D modeling and cross-sectional image analysis of the terrain. The results of working with each software have different extensions, and for data compatibility, the conversion process has been frequently considered in consideration of the suitability of the software.

3. DATA PROCESSING AND MODELING

3.1. Two–dimensional plane modeling

The excavation of the Ssangsujong area was carried out in two major steps. It was confirmed that various soil layers were distributed from the Joseon Dynasty layers at shallow depths to the Baekje Kingdom layers in deep depths. In this process, light wave surveying was performed twice by dividing the depth, and 3D scanning was performed only during the first excavation survey to record the overall shape of the terrain.

In order to infer the ground surface by period, the point where the cornerstone of the building site is located was taken as a reference point. The cornerstone of the Joseon Dynasty was manufactured by processing the stone material.

<table>
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Deviation average: -0.104
and the upper surface of the cornerstone was measured with light waves and the elevation value was corrected as much as the thickness of the cornerstone.

On the other hand, buildings in the Baekje and Silla periods did not use cornerstones, and the pillars were installed by laying gravel or drilling holes in the ground. The building site with a hole in the ground is different from the ground level in each period, and the elevation value of the point which is parallel to the surrounding soil layer was used.

In light wave surveying, a person manually adjusts the light source using a telescope, and errors may occur depending on the skill level of the person using the device, the survey environment, and the method of setting the reference point. Therefore, to examine the error vectors of the elevation values, the deviation and overall tendency were confirmed by comparing the elevation values for the same points of the light wave measurement and 3D scanning data. In result, the elevation value measured by light wave was 0.104 m lower on average (Table 1).

It was found to have low elevation values of cadastral survey at all points, a collective error that occurred during the measurement process. In some points, a large deviation of 10 cm or more was observed between the 3D scanning and cadastral survey data. There is a difference in the time of acquisition of the two data, and it is discussed that the topography has been artificially changed during the archaeological excavation process.

Since the 3D scanning data was performed only once, data by cadastral survey were used because it was not possible to secure data on the surface of the ground in various periods. Since the error of the same trend occurs in all data, if a precise reference point for the current topography is established, the relative position of the topography by the period can be interpreted.

The historical elevation value obtained through shape information on the current terrain and cadastral survey data...
conducted during the excavation survey was used as basic data under study, corresponding to an altitude above sea level. However, the sea level has difference due to geological factors in the past, and this difference caused on the uplift and subsidence of the topography was not reflected.

To standardize the elevation value, a point where the topography has hardly changed from the Baekje period to the present is set as a reference point, and the deviation from the current topography can be calculated to check the change according to the period. In the case of soil or trees, location changes may occur depending on creep or growth. It was selected based on the exposed bedrock at 80 m above sea level with the highest elevation value in the Ssangsujeong area under study.

In order to prepare a contour map by period, the results of a cadastral survey of a total of 90 points were used. Among these, 46 points is elevation value for the surface of the Baekje Kingdom, 21 points in the Unified Silla period, and 23 points in the Joseon Dynasty (Figure 2). These were calculated how much the elevation value corresponding to each period is located below the current surface and created a contour map for each period using the Kriging interpolation method.

In result, the elevation value of the Baekje period is located at an average of 0.65 m below the current topography. During the Unified Silla period, it has a depth of 0.61 m, almost similar to that of the Baekje period. However, the reference plane of the Joseon Dynasty was found to be distributed at a depth of about 0.40 m from the current surface, confirming a difference of more than 0.20 m from the topography of the Baekje and Unified Silla periods (Figure 3). This difference in depth means that deposition by weathering proceeded over time.

Figure 3. Maps showing the contour changes around the Sssusujeong area by period.
3.2. Topographic analysis

A contour line is a collection of the same elevation points, and in the coordinate system, the Z-axis has the same value, but the X- and Y-axis are in the form of vectors including directions and value. Since vector type data does not distort actual, it has an excellent spatial matching of the data and high resolution. Meanwhile, due to the high complexity of the data, it requires high-end hardware and a long time to compute it. For efficient analysis, it needs to be converted into raster data that inputs information into individual pixels. Raster data is a form of inputting information into each pixel. It is digital elevation model used widely, in which elevation values are entered into each pixel. To convert the contour plot, which is vector data, an triangulated irregular network model was applied, and the elevation value was input by dividing it into pixels. If the pixel size of the digital elevation model has controlled smaller, the resolution increases. In this study, considering the size of the soil layer, one pixel is set up units of several centimeters to observe changes in the topography.

Digital elevation models were produced according to the

Figure 4. Topographical modeling results around the Ssangsujeong area by period.
period to analyze the slope and aspect of the topography in Ssangsujeong area. In particular, a slope angle is closely related to the environment in which erosion and deposition occur. In addition to the slope, the density of sediments, precipitation, and distribution of vegetation have a comprehensive effect (Figure 4).

To distinguish the difference in sedimentation and erosion by the period, it is necessary to infer the environment at the period, although it is difficult on current research data. Therefore, we used factors caused in erosion and sedimentation in general conditions as the standard under study. Above all, the slope was distributed because erosion predominantly occurs when the slope exceeds 15°, the lower limit of debris flow occurrence (Kim and Lee, 2014).

For the aspect, the direction was divided into eight equal parts to distinguish colors, and the difference in inclination was marked with shades to visually express the change in the overall topography. In the case of inclination, different colors were expressed based on 15° to confirm macroscopic topographical changes, and microscopic changes in the terrain were reviewed by dividing them into 3° units for slopes smaller than 15°. As a result of the topographic analysis of the basic model corresponding to the current topography, it has a steep slope of around 15° around the peak of the Ssangsujeong area. The slope extends long to the east, so the flat land is widely distributed south of the Ssangsujeong. However, it has a characteristic that the slope becomes gentler toward the end (Figure 4).

Unlike the basic model in which the slope was developed to the east, the topography of the Baekje Kingdom was short and steep in the length of the slope to the east of the peak, and a gentle slope was developed in the south direction. The topography of the Unified Silla period appeared identical to that of the Baekje Kingdom, and it seems that the area of topography was maintained without any significant changes in both periods. However, during the Joseon Dynasty, the slope area around the peak widened in the east and south directions, and the area of relatively flat topography decreased. It is appeared the slope around peaks having an inclination of more than 15° over all eras, so erosion is likely to occur predominantly.

3.3. 3D modeling and cross-section analysis

3D modeling was performed virtually to restore the shape of the topography around the Ssangsujeong area and to examine the changes in the topography by cutting the cross-section. It is performed in many ways from nano-sized objects to urban planning over several kilometers. In conservation science, 3D scanning technology is actively applied to record shape information on the original form of cultural heritage (Lee et al., 2012), and scanning data is modeled and used for scientific analysis or tourism product production (Lee et al., 2005; Jo and Lee, 2009; Jo and Lee, 2011; Jo and Lee, 2012). Recently, geographical information has been analyzed through digitalization of current topography and archaeological excavation data to estimate paleotopography or review location conditions (Heo and Yang, 2021; Lee, 2022).

However, there are a few cases in which the changes in the topography according to each era are converted into geographic information based on the excavation data and

Figure 5. Diagrams showing the cross-section topography around the Ssangsujeong area using 3D modeling.
analyzed by 3D modeling. In this study, the shape of the 3D
topography of the time was modeled using a contour map
by the period, and the shape of the cross-section was compared
to examine the change in the topography (Figure 5).

To increase the resolution of the modeling, the grid unit
of the 3D shape should be set to the smallest size possible,
and one grid was set to tens of centimeters as the actual terrain
to confirm the change in delicate terrain. As a result of this
modeling, it was possible to identify the slope where
Ssangsujeong area is located and the flat land around it and
to confirm the topography change visually.

Although the 3D modeling data can confirm the visible
topography change, the quantitative comparison is difficult,
so the topography of area changes were examined by cutting
quantitatively and overlapping sections from 3D modeling
data. Since the change in the topography according to period
mainly changes around the eastern slope of the peak, where
Ssangsujeong is located, the cross-section in the east-west
direction was compared around the peak (Figure 6).

Flat lands in Ssangsujeong area exceed 100 m in left and
right width, and changes in altitude occur within a small
range within 10 m, making it difficult to confirm changes
in fine terrain when compared in the same scale (Figure 6).
Therefore, the change pattern was observed by amplifying the
accumulation of the Z-axis corresponding to the altitude
above sea level.

As a result of overlapping the topography of all periods
from the Baekje period to the present, there are little change
in the topography according to the times in the peak and flat
land where Ssangsujeong Pavilion is located, and the
thickness and slope change around the slope. It can be seen
that the topography hardly changed from the Baekje
Kingdom to the Unified Silla period, and the sediments
thickly accumulated around the slopes in the Joseon Dynasty.
In the cross-section of the current basic model, the area of
the flat land increases as the level of slope, so it is judged
that there was an effect by artificial clearing activities caused
in natural erosion and deposition.

4. DISCUSSIONS

4.1. Sedimentation and human activities

In this study, to analyze the topographic variations around
the Ssangsujeong of the Gongsanseong Fortress, the rock
distribution and the effects of erosion and sedimentation were
examined. The Ssangsujeong area is composed of migmatitic
gneiss, and dyke intrusion is not observed around it.
Therefore, there is no difference in the weathering
mechanism depending on the rock species, and only the
difference in weathering resistance due to the heterogeneity
of the rock is likely to exist.

The soil in this area corresponds to weathering soil of

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Figure 6. Variations of cross-section for topography
around the Ssangsujeong area by period.
migmatitic gneiss, and it requires much energy to be transported due to its low clay content and high content of sand and relatively large particles. Sediment transport is carried out by fluids such as running water, wind, and glaciers, and also the most process of the sedimentation occurs predominantly in environments such as rivers, seas, and lakes. However, the research area is an onshore sedimentary environment consisting of the foot of a mountain or plain, and sediments are mainly moved by precipitation and gravity. They are closely affected by the topography of the area.

Archaeological excavations have been conducted at various points in Gongsanseong Fortress more than a few times. The excavation depth varies depending on the altitude above sea level and the distribution of the topography. In case of Gongbukru, which corresponds to the north gate, to reach the excavated culture layer of the Baekje Kingdom, at least 4 m from the surface must be excavated and it can be found up to a depth of 7 m.

The area of Gongbukru is the lowest place in Gongsanseong Fortress, and two valleys are developed in the direction of Gongbukru, making it easy to transport sediments. On the other hand, in the excavation of the Ssangsujeong area, which corresponds to the highlands, the excavated culture layer is excavated in the shallow part of about 1 m. It is interpreted that the rate of accumulation of sediments in the Ssangsujeong area is very slow compared to the lowland area.

The slope near the peak in the Ssangsujeong area inclines more than 15°, so the sediment formed by weathering can be transported to the lower side of the slope. However, the soil must have been continuously deposited because the sediment movement is limited on flat land. The soil on the slope will stabilize as it gradually moves in the direction of gravity due to precipitation or creep, and sediment will gradually accumulate on the flat land. Therefore, if there are no artificial human activities, the culture layer of Joseon Dynasty should be located in higher than the Baekje period because sediments continuously accumulate all over time.

As a result of examining the changes in the topography by all periods, differences in the depth of the excavated culture layer are observed around the slope. However, in flat land, the excavated culture layer of various periods tends to appear at almost the same depth. Thus, it is difficult to explain the topographic changes in the Ssangsujeong area only through natural topographic changes, and there is a possibility that artificial reclamation activities have progressed.

Figure 7. Diagrams showing the spatial changes and human activities around the Ssangsujeong area by period.
4.2. Topographic change and space utilization

There is no research data on when the topography of the Ssangsujeong area began to have this shape. In the archaeological field, it is assumed that a large-scale human activity was carried out to build facilities after constructing the Gongsanseong Fortress. The location condition of Gongsanseong Fortress presents that it can effectively block enemies coming down from the north by using the natural topography of the Geumgang river and Mt. Gongsan. In particular, the Ssangsujeong area is located at the highlands in the south, so it is a crucial point where people in the fortress can look down on the situation in the north.

Besides, it has known as the presumed royal palace site because there are many historical building sites in the flat area around Ssangsujeong Pavilion result in the excavation survey. Therefore, to install ancillary facilities performing administrative functions and create a space for people to work, cutting the slope and flattening the flat land must have been performed (Figure 7A). The flat land formed in this way was continuously used during the Unified Silla period, and the minimum flattening work was performed for space utilization (Figure 7B).

Since then, Gongsanseong Fortress was not been actively utilized in the Goryeo Dynasty. In the Joseon Dynasty, there was Chungcheong Gamyeong, an administrative agency, in Gongsanseong Fortress, and the entire topography was reorganized. After the Unified Silla period, sediments caused by erosion continued to flow in, and the topography of the flat land would have partially changed (Figure 7C), and it seems that the excavated culture layers of Baekje and Unified Silla period were used in the process of human activities to utilize the flat land (Figure 7D).

However, the method of utilizing the sloping terrain seems to having changed by periods. Before the Joseon Dynasty, historical buildings were built on flat land by cutting all slopes. While in the Joseon, the topography of the slope was never processed, and the foundation stone was installed on it (Figure 7E).

This difference reflects the architectural techniques of the Joseon Dynasty, which used the natural topography as it is and adjusted the height of the pillars. Therefore, it is interpreted that the difference in the excavation depth of the excavated culture layer according to the period on flat land and slopes was influenced by the use of space and changes in construction techniques.

The space around Ssangsujeong area was continuously used during the Japanese colonial and modern times (Figure 8A). During the Japanese colonial period, it was used as a horse yard for grazing and raising horses, but in modern times it was used just as a playground (Figure 8B, 8C). In this circumstance, the flattening was continuously performed. The slope was cut as much as possible to secure the most expansive space, and the current condition was maintained.

The topography of the Ssangsujeong area has been utilized throughout the ages and it has been continuously managed through the needs of the human life. It means that the Ssangsujeong area has a vital location within the Gongsanseong Fortress, so the value of space utilization is excellent, and these characteristics could be indirectly confirmed through changes in the topography.

The topographic analysis technique applied in this study reviewed the changes in topography according to the periods based on archaeological excavation data and current geographic information. However, archaeological excavation is carried out in a limited range, and due to this, it can be applied in a limited range around the flat land in the Ssangsujeong area. Moreover, most of the excavation data in the archaeological field exist in analog form. There are many cases where the amount of data is insufficient, such as the

Figure 8. Utilization of the flat land around the Ssangsujeong area in modern time. (A) is a scene on the Japanese colonial period in 1920, (B) and (C) show this place is used by playground in 1960s.
absence of 3D scanning data or performing only simple cadastral surveys.

In order to apply the analysis of the topography to various archaeological sites in the future, 3D scanning must be performed during the excavation process to secure the surface shape data by the periods, and database have to be established through the archiving of digital data. Also, if scientific analysis results are collected together, it is expected that the restoration of highly reliable paleotopography will be possible to restore.

5. CONCLUSIONS

1. Gongsanseong Fortress, the subject of the study, has been continuously excavated from the 1980s to the present, and excavated culture layers of the Baekje Kingdom, Unified Silla period, and Joseon Dynasty appear at various depths depending on the surrounding terrain and location. In the study, the geological and topographical status of the Gongsanseong Fortress was analyzed, and the excavation data of the Ssangsujeong area were reviewed to analyze the transition process of the paleotopography according to the periods.

2. The Ssangsujeong area corresponds to the highlands where the peaks are located and a vast flat land has been created. The flatland has a length of about 100 m in the east-west and north-south directions, and in the northwest of the flatland, the slope with an elevation of 81 m above sea level is distributed around the peak. Rock species composing this area is only migmatitic gneiss type, and the boundary of other rocks or intrusion of dikes cannot be confirmed.

3. During the excavation, the elevation values of the excavated culture layers of the Baekje Kingdom, Unified Silla period, and Joseon Dynasty were measured and recorded. The overall distribution of the layers could be confirmed by performing 3D scanning. In order to examine the reliability of the survey result, it was compared with the 3D scan data. Although a slight deviation was confirmed between the two data, the overall trend was similar. Therefore, the current topography was set as a reference, and the depth of the stratum corresponding to each period was calculated and extracted as digital data, which is expressed in the 3D coordinate system.

4. The obtained coordinations are in the form of points, and the elevation value between points must be inferred through geostatistical techniques to confirm the shape of the topography. Thus, Kriging interpolation was applied, and connecting points created a contour map with the same altitude value. In result, it was found that the contour lines of the Baekje Kingdom and the Unified Silla period were almost identical. However, it was confirmed that the slope was distributed over a relatively wide range in the Joseon Dynasty.

5. Applying an triangulated irregular network model to the contour map by period was converted into raster data, and the slope and aspect were modeled. As a result, it was found that the slope angle had high and the flat land showed vast during the Baekje Kingdom and the Unified Silla period. On the other hand, during the Joseon Dynasty, the slope became gentle, and the space of the flat land became somewhat narrow.

6. A polygon model was produced through a 3D modeling process for the topography. The elevation change was confirmed by cutting a cross-section around the peak and overlapping it. As a result, it was found that there was little change in elevation in the Baekje Kingdom and Unified Silla periods, and some difference in the shape of the slope with the Joseon Dynasty. Although the elevation value of the slope varies according to period, the elevation value of the flat land shows almost the same depth regardless of period.

7. If sedimentation has continued in the Ssangsujeong area, the stratum of the ancient era should be located in the lower part. However, regardless of the period, the flat land has the same elevation value, indicating that artificial human activities continued in the Ssangsujeong area. Unlike the Baekje Kingdom and Unified Silla periods, when buildings were built after flattening the terrain. It was interpreted that the construction technique using the natural terrain was applied during the Joseon Dynasty.

8. The change trend in the topography of a narrow area was reviewed for the range in which the excavation survey was conducted under study. These research techniques can be analyzed only by synthesizing research results in various fields. For this reason, a database must be constructed by digitally converting analog data and collecting 3D shape information. If these data are comprehensively interpreted, it is expected that paleotopography reconstruction with higher reliability will be possible, and the analysis method under
study will be proper to restore paleotopography.

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