A STUDY OF THE *ANGBU-ILGU*: A SCAPHE SUNDIAL CREATED DURING THE REIGN OF KING SEJONG OF JOSEON, AND ITS EVOLUTION OVER TIME

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Abstract: The *Angbu-ilgu*, a hemispherical sundial, was created in 1434 by Jeong In-Ji, Yi Sun-Ji, and others, in collaboration with King Sejong. This study investigates the creation of the *Angbu-ilgu* and its subsequent evolution. Through historical records and analysis of the extant examples, the Sejong *Angbu-ilgu* has been reconstructed, revealing unique features such as a rotating pinhole plate, celestial circumference degrees, 100 daily intervals, and depictions of animal gods. These characteristics highlight its innovative design and influence on later sundials. This research further explores the diversification of *Angbu-ilgu* in the late Joseon Dynasty, with variations in size, design, and materials reflecting the evolving technological landscape. By tracing this evolution, this study seeks to illuminate Korean astronomical traditions, along with contributing to a deeper understanding of Joseon-era scientific advancements.

Keywords: *Angbu-ilgu*; scaphe sundial; King Sejong; pinhole plate; circular prop; flower-bud stylus; 24 solar-term lines; 12 dial lines; 12 animal gods; hour lines of the 12 double-hours and 100 intervals.

1 INTRODUCTION

King Sejong of Joseon (世宗, 1397–1450, r. 1418–1450) made various scientific and technological advancements in the realms of astronomy, agriculture, weaponry, and printing. His representative achievement in astronomy is the creation of the *Angbu-ilgu* (仰釜日晷), a hemispherical sundial modeled on the shape of the celestial sphere. This type of sundial is thought to have originated in the Babylonian region in the third century BC (Lee, 1982). In the first century AD, Marcus Vitruvius Pollio (c. 80–15 BC), a mathematician and architect during the reign of the Roman Emperor Augustus, explained in Book 9 of *De Architectura* that Berosus (fl. third century BC), a Babylonian, invented a truncated hemispherical sundial, and Dionysodorus (c. 250–190 BC) invented a conical sundial (Evans, 1998). Additionally, Apollonius of Perga (262–190 BC) of ancient Greece introduced conic sections, the practical purpose of which is known to have been sundial construction (Neugebauer, 1948). In the mid-tenth century, during the revival of Islamic science, Al-Ḥuǧandī (fl. tenth century AD) published a paper on the universal instrument, a hemispherical sundial (Sezgin, 2010). Furthermore, the *Angyi* (仰儀), a hemispherical sundial, was produced in 1276 in the Yuan Dynasty.

In Joseon Korea, King Sejong initiated a project to produce astronomical instruments from July 1432 (14th year of his reign) to January 1438. During this period, the *Ganui* (簡儀, 1433), *Gyupyo* (圭表, 1435), *Borugak-ru* (報漏閣漏, 1434), *Angbu-ilgu* (仰釜日晷, 1434), *Cheonpyeong-ilgu* (天平日晷, 1436–1437), *Hyeonju-ilgu* (懸珠日晷, 1436–1437), and *Heumgyeonggak-ru* (欽敬閣漏, 1438) were developed in the Royal Astronomy Office (書雲觀) of Geongbok-gung Palace (景福宮) (Mihn et al., 2016). However, all extant *Angbu-ilgu* are known to have been produced in the late Joseon Dynasty (Kim et al., 2022; Yun et al., 2023). This study examines the *Angbu-ilgu* pro-

Figure 1: The extant *Angbu-ilgu* designated as Korean Treasure No. 845, preserved at the National Palace Museum of Korea: (a) CD12943, (b) CD12944 (after Mihn et al., 2024).

duced during the reign of King Sejong (hereafter referred to as the Sejong *Angbu-ilgu*), and compares this instrument to the extant *Angbu-ilgu* in Korea.

2 EXTANT *ANGBU-ILGU*

Jeon (1975: 64–67) first introduced the *Angbu-ilgu* based on existing artifacts. In 1985, two *Angbu-ilgu*, then housed at the National Museum of Korea (國立中央博物館) in Seoul and the Yeongneung (英陵, King Sejong's Tomb) Royal Tombs Center in Yeoju, were together designated as Korean Treasure No. 845 (OCP, 1985). These two treasures are currently preserved at the National Palace Museum of Korea (國立古宮博物館), with inventory numbers CD12944 and CD12943 (see Figure 1). Figure 2 depicts the appearance of the CD12944 *Angbu-ilgu*.

Made of copper, CD12944 has the following external features (OCP, 1985). Inside its 13.8 cm-radius hemisphere, several lines are drawn, forming a sundial. A stylus, shaped like a flower bud, is placed perpendicular to the South Pole of the hemisphere. Its length is equal to the hemispherical radius, with the tip of the bud-stylus located at the center of the hemisphere. The *Angbu-ilgu* hemisphere's thickness is approximately 8 mm. A 3.8 cm-thick ring, called the horizon ring, joins the hemisphere's boundary. Below the horizontal ring are four pillars, which are shaped like dragons ascending to the sky amidst clouds. These four pillars are fixed to a cross-shaped column stand resembling two intersecting troughs. This cross-shaped trough stand ensures that the *Angbu-ilgu* is level by using water.

The hemisphere and horizon ring of the *Angbu-ilgu* include various lines, along with information written in Chinese characters. The dial lines, corresponding to 12 double-hours, radiate from the South Pole inside the hemisphere, and 13 parallel lines above and below the equator represent the 24 solar-term lines. The northernmost solar-term line is the winter solstice line, and the southernmost one is the line representing the summer solstice, which is near the nadir of the celestial hemisphere of the *Angbu-ilgu*. The remaining 11 solar-term lines include both solar terms; for example, the equator line, which corresponds to the vernal and autumnal equinoxes. Between the winter solstice line and the summer solstice line, hour lines are drawn, representing 12 double-hours and 96 quarter-hours. The 12 double-hour names are engraved in Chinese characters on the 12 dial lines below the summer solstice line. As the 12 double-hours are divided into two equal parts, called the initiation (初) and center (正), they are each equivalent to one hour in the modern time system.

The 24 solar-term names are written on the horizon where the corresponding solar-term lines intersect. For instance, on the East side, there are 13 solar-term names, from North to South: *Dongji* (winter solstice, 冬至), *Sohan* (minor cold, 小寒), *Daehan* (extreme cold, 大寒), *Ipchun* (spring entrance, 立春), *Usu* (rainwater, 雨水), *Gyeongchip* (breaking hibernation, 驚蟄), *Chunbun* (spring equinox, 春分), *Cheongmyeong* (clean and clear, 淸明), *Gokwoo* (spring rain, 穀雨), *Ipha* (summer entrance, 立夏), *Soman* (milky grain, 小滿), *Mangjong* (full grain, 芒種), and *Haji* (summer solstice, 夏至). On the West side are 13 names of solar terms, from South to North: *Haji* (summer solstice), *Soseo* (minor heat, 小暑), *Daeseo* (extreme

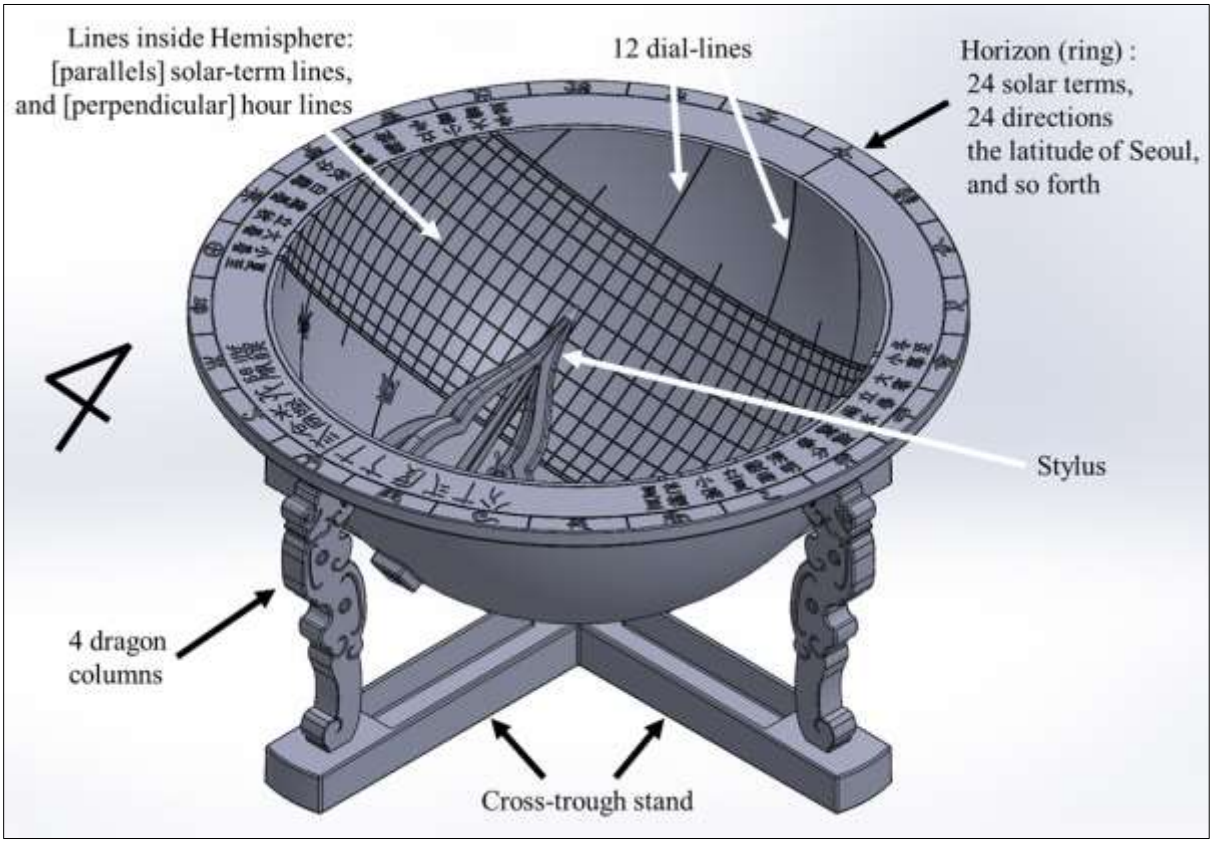


Figure 2: Appearance of the CD12944 *Angbu-ilgu* (diagram: the authors).

treme heat, 大暑), *Ipchu* (autumn entrance, 立秋), *Cheoseo* (heat edge, 處暑), *Beakro* (virgin dew, 白露), *Chubun* (autumn equinox, 秋分), *Hanro* (cold dew, 寒露), *Sanggang* (frost downfall, 霜降), *Ipdong* (winter entrance, 立冬), *Soseol* (light snow, 小雪), *Daeseol* (heavy snow, 大雪), and *Dongji* (winter solstice).

On the South side of the horizon ring is engraved the North Pole altitude of Hanyang (Seoul): 37° 20′ (漢陽北極高三十七度二十分). The North side of the CD12944 *Angbu-ilgu*'s ring is blank, but other examples have the inscription "*Angbu-ilgu* (仰釜日晷)".

The names of the 24 directions are engraved on the edge of the horizon ring. On the horizon, the sides near the base and the pointed direction of the bud-stylus are the South (午, *o*) and the North (子, *ja*), respectively. East and West are marked by *myo* (卯) and *yu* (酉) on the horizon ring, respectively.

It is noteworthy that all the relics except for the CD12944 *Angbu-ilgu* have 37° 39′ 15″ inscribed as the North Pole altitude of Hanyang (Seoul). In 1731, when Mu Ke-Deng (穆克登, 1664–1735) of the Qing Dynasty came to Joseon as an imperial envoy with Wuguan Sili (五官司曆), He Guo-Zhu (何國柱) measured the North Pole altitude as 37° 39′ 15″ using a quadrant (象限儀) on Jongno (鐘路) Avenue in the center of Hanyang (漢陽) (Goo, 2019: 318–319; Lee, 1984). This suggests that only the CD12944 *Angbu-ilgu* was made before 1731.

Except for CD12944, most *Angbu-ilgu* have similar radii of 9.4–9.5 cm, with the horizon rings having a thickness of 2.8 cm (Mihn et al., 2023). In 2022, three *Angbu-ilgu* housed in the National Palace Museum of Korea, Gyeongju National Museum, and Sungshin Women's University Museum, respectively, were designated as Korean Treasures. These *Angbu-ilgu* have four pillars with similar sculptures of ascending dragons, each with a flat stand made of brass, not bronze (Yun et al., 2023).

3 THE FIRST *ANGBU-ILGU* IN THE REIGN OF KING SEJONG

An account of the *Angbu-ilgu* inscription written by Kim Don (金墩, 1385–1440) has been preserved in the *Veritable Records of King Sejong* (世宗莊憲大王實錄). This scaphe sundial, called the Sejong *Angbu-ilgu*, was created in the 10th lunar month of 1434 by Jeong In-Ji (鄭麟趾, 1396–1478), Yi Sun-Ji (李純之, 1406–1465), and others, in collaboration with King Sejong (Mihn et al., 2016). The Sejong *Angbu-ilgu* is thought to have been influenced by the Yuan Dynasty (元)'s *Angyi* (仰儀) according to the *Gukjo-yeoksang-go* (*Compendium of the Heavenly System and Astronomical*

Instruments in the Joseon Dynasty, 國朝曆象考) (1796),[1] This *Angbu-ilgu* is reported as having been manufactured based on the description of the *Angyi* (仰儀) found in the *History of the Yuan Dynasty* (元史) (Lee and Moon, 2004: 160–175). This theory is highly plausible, as the *Angyi* (仰儀) is introduced in the *Jega-yeoksang-jip* (*Collected Discourses on the Astronomy and Calendrical Science of the Chinese Masters*, 諸家曆象集) that was published by Yi Sun-Ji in 1445. It is interesting to note that the *Angbu-ilgu* inscription in the *Veritable Records of King Sejong* is similar in literary style to the *Angyi* inscription of the *History of Yuan Dynasty* (元史). The *Angbu-ilgu* inscription is included below:

> No instrument is more important than one that keeps time. The clepsydra marks the time at night, but there is none to tell the time during the day.
> A sundial is cast by copper, its shape is akin to a hemisphere. The circular prop, set upon the meridian line, aligns with south and north.
> The pinhole (plate) bends and rotates, following the sun, and it resembles a mustard seed. Half of the celestial circumference degrees are drawn within (the hemisphere).
> The figures of the god of the 12 double-hours were drawn (upon the hemisphere) for all to see. The projected shadow of the sun appears on each line so that the time can be known.
> It was installed on the main street of Seoul, where people gather. Since this sundial tells the time during the day, the people can easily make use of it.[2]

Through this inscription, the characteristics of the Sejong *Angbu-ilgu* appear to differ from those of the extant *Angbu-ilgu*.

First, the circular prop (圓距) placed on the meridian resembles the flower-bud stylus in the extant *Angbu-ilgu*. The circular prop has a pinhole, which must rotate to follow the Sun. The *Angyi* in the *History of Yuan Dynasty* has a pinhole in the middle of the *Xuanjiban* (旋璣板) or *Jiban* (璣板), which moves at two axes of rotation (Pan, 2005). It is thought that the Sejong *Angbu-ilgu* also had a plate with a pinhole, like the *Xuanjiban*. The pinhole plate of the Sejong *Angbu-ilgu* rotated while attached to the circular prop (see Figure 3(b)).

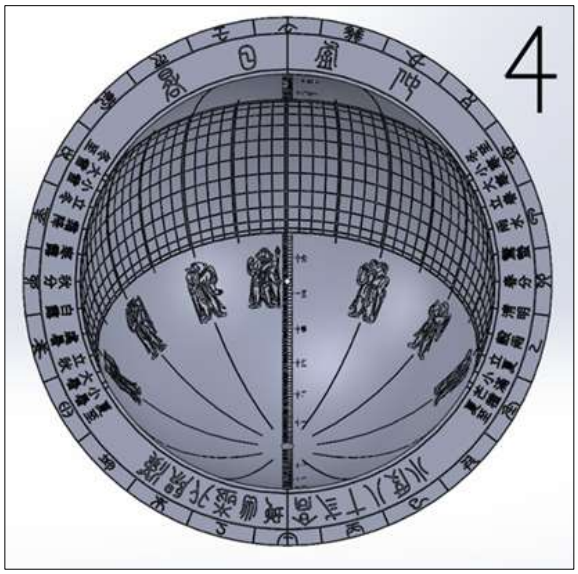
Second, the Sejong *Angbu-ilgu* had the celestial circumference degrees drawn inside the hemisphere. The unit of the celestial circumference degrees is *du*, where 365.25 *du* = 360°. The meridian line of the *Angbu-ilgu* hemisphere also has the celestial circumference degrees drawn on it, and its scale seems to have started at the South Pole. It is uncertain if the celestial circumference degrees are drawn on all 12 dial lines representing the 12 double-hours. These celestial circumference degrees are used to draw 13 solar-term lines, like those on the extant *Angbu-ilgu*. Among the astronomical instruments handed down from the time of King Sejong, the one with the celestial circumference degrees is the ring of the *Ilseong-jeongsi-ui* (Sun-and-stars Time-determining Instrument, 日星定時儀) excavated in Seoul in 2021. This ring is about 2 *ja* (about 42.0 cm) in diameter and has 1,461 graduations of 365 *du* ¼ (1 *du* = 4 fractions) (Mihn et al., 2023).

Third, the Sejong *Angbu-ilgu* also had lines indicating the time, similar to the existing *Angbu-ilgu*. However, it consists of 100 intervals instead of 96 quarter-hours in a day, with each interval lasting 14.4 minutes (compared to the 15 minutes of a quarter-hour). In addition, each interval is divided into six fractions, resulting in a total of 600 graduations engraved on the hemisphere's surface, with fewer than 300 graduations on the winter solstice line and more than 300 graduations on the summer solstice line. Also, each double-hour is divided into two parts—the initiation (初) and center (正)—which equates to an hour in modern timekeeping. Each half double-hour consists of four intervals and one fraction, making a total of 25 graduations (Lee, 2003).

Fourth, above each of the 12 dial lines, the Sejong *Angbu-ilgu* features depictions of animal-faced gods for each of the 12 double-hours, representing 12 earthly branches. These animal gods engraved on the hemisphere differ from the extant *Angbu-ilgu*, which have the names of the 12 double-hours carved in Chinese characters. Additionally, all the lines and characters of the Sejong *Angbu-ilgu* were inlaid with silver, like the extant *Angbu-ilgu*. Figure 3 and Figure 4 depict the model of the Sejong *Angbu-ilgu* featured in this study.

A bar handle attached under the pinhole plate allowed for effortless operation of the plate. The following text is included in the *Donggyeong-jiji* (*Chorography of Joseon*, 東國地誌).

> ... a stone pedestal was erected, and an Angbu-ilgu was placed on it. The inside of the Angbu-ilgu was engraved with the celestial circumference degrees, and the 12 animal gods were drawn. On the outside, the 24 cardinal directions were displayed. A hyeong (bar handle, 衡) was installed in the north and south, and a pinhole was drilled in the waist of the hyeong to measure the shadow of the sun.[3]



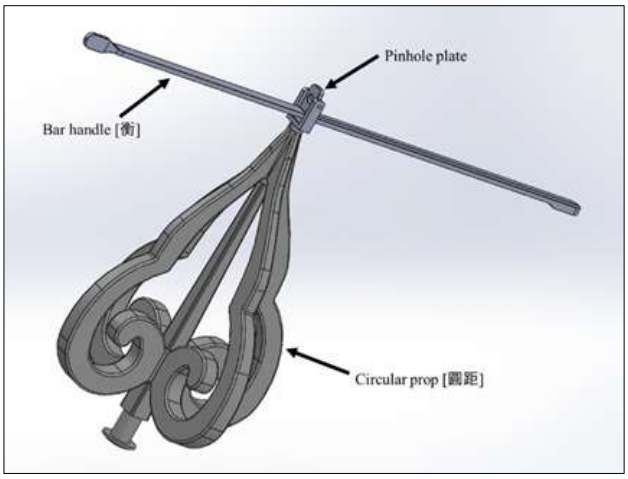


Figure 3: A model of the Sejong *Angbu-ilgu*; (left): hemisphere and horizon; (right): the circular prop and pinhole plate (diagrams: the authors).

Figure 4: 3D-printed model of the Sejong *Angbu-ilgu* in this research; (left): scene estimating time; (right): sunlight passing through the pinhole projected on the hemisphere (photographs: the authors).

Like the alidade or dioptra in the declination ring of an armillary sphere, the Sejong *Angbu-ilgu* had a bar-shaped handle under the pinhole plate. This bar served as a handle to easily rotate the pinhole plate up and down, clockwise and counterclockwise. According to the above text, the Sejong *Angbu-ilgu* also marked 24 directions on the horizon ring, which is the same as the extant *Angbu-ilgu* (see Table 1).

King Sejong had instructed that *Angbu-ilgu* be installed in two places on Jongno Avenue in Seoul. At one of them, a stone pedestal was excavated in the early 1900s at a site in front of the Jongmyo Shrine (宗廟) and is currently preserved in Jongmyo Square Park. This stone pedestal is an artifact that verified the description in the C*horography of Joseon* that "The *Angbu-ilgu* was installed on a stone pedestal." The upper side of the stone pedestal is a plane measuring 83 cm × 83 cm (length × width). There are six round grooves spaced about 12 cm apart on the upper side, making the total length about 60 cm. The CD12944 *Angbu-ilgu* has a ratio of 11:3 between the radius of the hemisphere and the thickness of the horizon ring. As mentioned earlier, the hemispherical surface of the *Angbu-ilgu* features solar-term lines and dial lines carved on its surface, which show the hour lines of the 12 double-hours and 100 intervals and mark the graduations of the celestial circumference in degrees, respectively.

The least optimal diameter for drawing these type of lines (the solar-term lines and hour lines) inside the same circle (or sphere) is 2 *ja* (41.4 cm) (Mihn et al., 2017). The outer diameter of the horizon ring of the Sejong *Angbu-ilgu* measures 14/11 of 2 *ja*, which is approximately 2.54 *ja* (52.7 cm). If there was a dragon pillar under the 52.7 cm horizon ring, the cross-shaped trough stand can be estimated to have had a width of at least 53 cm. This is similar to the length of the six round grooves of the *Angbu-ilgu* stone pedestal. Ultimately, the diameter of the hemisphere of the Sejong *Angbu-ilgu* is estimated to have been 2 *ja*

Table 1: Celestial circumference degrees of the 24 solar terms from the South Pole of the Sejong *Angbu-ilgu*, made for Seoul's latitude of approximately 37.5° (after Park et al., 2023).

24 Solar Terms	Date	Day Number (after Winter Solstice)	Polar Distance, *p*	
			◦	du
Winter solstice (冬至)	22 December	01	115.09	115 1/4
Minor cold (小寒)	5 January	15	114.23	114 1/4
Extreme cold (大寒)	20 January	30	111.75	111 3/4
Spring entrance (立春)	4 February	46	107.88	108 0/4
Rainwater (雨水)	19 February	61	102.95	103 0/4
Breaking hibernation (驚蟄)	5 March	76	97.31	97 1/4
Spring equinox (春分)	21 March	91	91.31	91 1/4
Clean and clear (清明)	5 April	107	85.32	85 1/4
Spring rain (穀雨)	20 April	122	79.67	79 3/4
Summer entrance (立夏)	5 May	137	74.74	74 3/4
Milky grain (小滿)	21 May	152	70.87	70 3/4
Full grain (芒種)	6 June	167	68.39	68 2/4
Summer solstice (夏至)	21 June	183	67.53	67 2/4
Minor heat (小暑)	7 July	198	68.39	68 2/4
Extreme heat (大暑)	23 July	213	70.87	70 3/4
Autumn entrance (立秋)	7 August	228	74.74	74 3/4
Heat edge (處暑)	23 August	243	79.67	79 3/4
Virgin dew (白露)	8 September	259	85.32	85 1/4
Autumn equinox (秋分)	23 September	274	91.31	91 1/4
Cold dew (寒露)	8 October	289	97.31	97 1/4
Frost downfall (霜降)	23 October	304	102.95	103 0/4
Winter entrance (立冬)	7 November	320	107.88	108 0/4
Light snow (小雪)	22 November	335	111.75	111 3/4
Heavy snow (大雪)	7 December	350	114.23	114 1/4

(approximately 41–42 cm), which is 1.5 times larger than that of the CD12944 *Angbu-ilgu*.

The Sejong *Angbu-ilgu* is also 2.2 times larger than other extant *Angbu-ilgu*, except for CD12944. Because of the size of the Sejong *Angbu-ilgu*, it was possible to draw animal gods representing the 12 double-hours on its surface.

4 VARIOUS *ANGBU-ILGU* IN THE LATE JOSEON DYNASTY

The Sejong *Angbu-ilgu* led to the development of various types of *Angbu-ilgu* in the late Joseon Dynasty. Notably, there are the five *Angbu-ilgu* made of copper that were introduced in the previous section. Also, many other *Angbu-ilgu* have been handed down in Korea. For example, the National Palace Museum of Korea has an *Angbu-ilgu* with the inventory number CD26794. This *Angbu-ilgu*, like the CD12943 *Angbu-ilgu* (included as part of Treasure No. 845), is inscribed with the maker's name, Kang Geon (姜㻋, 1843–1909). These two were also created in the same year, 1899 (Mihn et al., 2024). Additionally, the History of Science Museum at the University of Oxford in England has an *Angbu-ilgu* made in 1873 by Kang Geon's older brother Kang Yun (姜潤, 1830–1898), but the four dragon pillars and cross stand have been lost (Lee et al., 2023). The National Agricultural Museum of Korea has an *Angbu-ilgu* with three dragon pillars and a three-branch stand, and the National Folk Museum of Korea (國立民俗博物館) and the Seiko Museum in Japan each have an *Angbu-ilgu* with three legs without a stand. The Korea University Museum (高麗大學校 博物館) has the same type as the National Folk Museum of Korea, but three legs have been lost (Yun et al., 2023).

There are also portable *Angbu-ilgu* made of ivory or jade (see Table 2). These portable *Angbu-ilgu* were exclusively made by the Jinju Kang clan, including the brothers Kang Yun, Kang Geon, and Kang Hong (姜泓, 1838–?), as well as Kang Geon's sons, Kang Ik-Su (姜益秀, 1871–1908) and Kang Mun-Su (姜文秀, 1878–1931).

Meanwhile, the Korea Meteorological Administration (KMA, 氣象廳) and the Seoul Museum of History (SMH, 서울歷史博物館) have been preserving slate *Angbu-ilgu* (see Figure 5). These *Angbu-ilgu* consist of a hemisphere carved in the middle of a polished slab. The KMA's stone *Angbu-ilgu* has an upper plate measuring 40.57 (±0.33) cm in length, 30.5 (±0.54) cm in width, and 26.0 cm in height, along with a hemisphere with a diameter of 21.8 cm. The SMH's stone *Angbu-ilgu* is 31.5 cm long, 23.1 cm wide, and 8.0 cm high, and the diameter of the hemisphere

Table 2: Portable *Angbu-ilgu* made by the Kang Geon (姜㻋) family.

No.	Institution of Ownership	Figure	Year of Manufacture	Material and Specifications (cm)	Creator	Reference
1	Whipple Museum of the History of Science, the Univ. of Cambridge		1862	Ivory	Kang Yun	Lee et al., 2023
2	History of Science Museum, the Univ. of Oxford		1870	Ivory	Kang Yun	Kim et al., 2010
3	National Palace Museum of Korea (Treasure No. 845)		1871	Jade 5.6 × 3.3 × 1.6	Kang Geon	Kim et al., 2010
4	Gyeonggi Province Museum		1873	Ivory 6.5 × 4.2 × 1.7	Kang Geon	Kim et al., 2010
5	National Maritime Museum in England		1873	Ivory	Kang Yun	Kim et al., 2010
6	National Palace Museum of Korea		1880	Ivory 10.3 × 5.8 × 3.4	Kang Yun	Kim et al., 2010
7	In China		1881	Ivory 6 × 3 × 2.2	Kang Hong	Kim et al., 2010
8	Yeongneung Royal Tombs, Yeoju		1901	Ivory 8.5 × 4.5 × 2.5	Kang Ik-Su	Kim et al., 2010
9	Seoul Museum of History		1908	Jade 7.2 × 3.1 × 3.8	Kang Mun-Su	Kim et al., 2010

is 13.55 cm (Kim et al., 2022). In addition, the Seoul National University Museum (서울大學校博物館) still preserves an *Angbu-ilgu* made of marble.

Except for CD12944, all *Angbu-ilgu* were made after 1731. Most of the artifacts whose makers have been identified are from the Kang Geon family and date from after 1862. King Cheoljong (哲宗, 1831–1863, r. 1849–1863) died without an heir, and King Gojong (高宗, 李熙, 1852–1919, r. 1863–1907) ascended to the throne in 1863. Most of the remaining portable and copper *Angbu-ilgu* date from the reign of King Gojong. It is presumed that the slate *Angbu-ilgu* were made during the Great Korean Empire (大韓帝國) (1895–1919) (Kim et al., 2022).

Figure 5: The slate *Angbu-ilgu* preserved by the Korea Meteorological Administration (left), and the Seoul Museum of History (right) (after Kim et al., 2022).

5 CONCLUDING REMARKS

In 1434, King Sejong, along with Jeong In-Ji and Yi Sun-Ji, created the *Angbu-ilgu*, a scaphe sundial inspired by the Yuan Dynasty's *Angyi*, which measured the date and time by projecting the Sun's image onto a hemispherical surface. This study examined the *Angbu-ilgu* and, based on historical records and analysis of the extant examples, reconstructed the design and features of this unique sundial. This paper's findings suggest that the Sejong *Angbu-ilgu* varied significantly from later versions, as it featured a rotating pinhole plate, celestial circumference degrees, 100 intervals for each day, and depictions of animal gods representing the twelve double-hours, highlighting its innovative nature and potential influence on later sundial designs.

Furthermore, this research sheds light on the diverse evolution of the *Angbu-ilgu* throughout the Joseon Dynasty. While the Sejong *Angbu-ilgu* appears to be a unique creation, later versions, particularly those crafted by the Kang Geon family in the late Joseon period, exhibit distinct features such as smaller sizes, simpler designs, and the use of materials such as brass, slate, and marble. This diversification reflects the evolving technological landscape and the *Angbu-ilgu*'s adaptation to different purposes and contexts.

In conclusion, the *Angbu-ilgu* stands as a testament to the scientific and technological advancements of the Joseon Dynasty. By tracing its development from the innovative Sejong *Angbu-ilgu* to its diverse forms in the late Joseon period, this study contributes to a deeper understanding of Korean astronomical traditions and their enduring legacy. Further research on the *Angbu-ilgu* and other Joseon-era scientific instruments promises to continue to enrich knowledge of Korea's rich scientific heritage.

6 NOTES

1. *Gukjo-yeoksang-go* (*Compendium of the Heavenly System and Astronomical Instruments in the Joseon Dynasty*, 國朝曆象考) is an astronomical book written in 1796 by Seo Ho-Su (徐浩修, 1736–1799) together with Seong Ju-Deok (成周悳, 1759–?) and Kim Yeong (金泳, 1749–1817).
2. *Veritable Records of King Sejong*, Volume 66, 10th-month 2, 1434, 凡所設施, 莫大時也. 夜有更漏, 晝難知也. / 鑄銅爲器, 形似釜也. 經設圓距, 子對午也. / 窾隨拗回, 點芥然也. 晝度於內, 半周天也. / 圖畫神身, 爲愚氓也. 刻分昭昭, 透日明也. / 置于路傍, 觀者聚也. 自今伊始, 民知作也.
3. *Dongkuk-jiji* (*Chorography of Joseon*, 東國地誌). ... 築臺置仰釜, 內刻周天度數畫十二神, 外列方位. 設衡南北 衡腰穿小竅 以測日晷. ...

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8 REFERENCES

Evans, J., 1998. *The History and Practice of Ancient Astronomy*. Oxford, Oxford University Press.

Goo, M.O., 2019. *Astronomical Instruments Repair Theory and Astronomical Instruments Policy in the Late Joseon Dynasty*. Seoul, Hyean Press.

Jeon, S.W., 1975. *Korean History of Science and Technology*. Seoul, Jeongeum-sa.

Kim, S.H., Lee, K.-W., and Lee, Y.S., 2010. A study on the sundials of the Kang family of Jinju. *Journal of Astronomy and Space Sciences*, 27(2), 161–172.
Kim, S.H., Yun, Y.H., Mihn, B.-H., Leem B.G., Yoon, M.G., and Leem, B.S., 2019. Operational model of time-keeping systems of Heumgyeonggak-Nu. *Publications of the Korean Astronomical Society*, 34(3), 31–40.
Kim, S.H., Mihn, B.-H., and Kim, J.Y., 2022. Analysis of Angbu-Ilgu, a stone material in the late Joseon dynasty. *Publications of the Korean Astronomical Society*, 37(3), 35–47.
Lee, E.S., 1982. The history of the sundial and its principle. *The Dong Bang Hak Chi*, 33, 81–156.
Lee E.S., 1984. The horizontal sundial made of marble and Crown Prince Sohyeon. *The Journal of the Korean History of Science*, 6(1), 124–126.
Lee, E.H., and Moon, J.Y., 2004. (Korean Translation of) *Gukjo-yeoksang-go* (*Compendium of Heavenly System and Astronomical Instruments in Joseon Dynasty*). Seoul, Somyeong Press.
Lee, K.-W., Mihn, B.-H., Kim, N.R., and Lee, S.G., 2023, Status of Korean astronomical heritage preserved overseas. *Publications of The Korean Astronomical Society*, 38(3), 147–160.
Lee, Y.S., 2003. The diurnal and nocturnal time measure using an astronomical instrument in Joseon Dynasty. *The Bulletin of the Korean Astronomical Society*, 28(1), 123–133.
Mihn, B.-H., Lee, M.S., Choi, G., and Lee, K.-W., 2016. Manufacturers of astronomical instruments invented during the Ganui-Dae Project in Joseon Dynasty. *Publications of The Korean Astronomical Society*, 31(3), 77–85.
Mihn, B.-H., Choi, G., and Lee, Y.S., 2017. Astronomical instruments with two scales drawn on their common circumference of rings in the Joseon Dynasty. *Journal of Astronomy and Space Sciences*, 34(1), 45–54.
Mihn, B.-H., Kim, S.H., Lee, Y.S., and Kim, J.E., 2023. Three rings of the Sun-and-Stars Time-Determining Instrument excavated in Insa-dong in Seoul. *Korean Journal of Palace Museum*, 16, 7–39.
Mihn, B.-H., Kim, S.H., Lee, Y.S., and Kim, J.E., 2024. Characteristics of *Angbu-ilgu* during the reign of King Sejong of the Joseon Dynasty. *Publications of The Korean Astronomical Society*, 39 (2), 69–87.
Neugenbauer, O., 1948. The astronomical origin of the theory of conic sections. *Proceedings of the American Philosophical Society*, 92(3), 136–138.
Office of Cultural Properties (OCP), 1985. *Actual Survey Report on Cultural Properties for Science and Technology.* Seoul, OCP.
Pan, N., 2005, *Caitu Ben Zhongguo Gudai Tianwen Yiqi Shi* (*Colored Version of the History of Ancient Astronomical Instruments of China*). Taiyuan, Shanxi Jiaoyu Chubanshe (in Chinese).
Park, J.W., Mihn, B.-H, Kim, S.H., and Kim, Y.G., 2023. Study on the restoration model of Jeongnam-Ilgu, created during the reign of King Sejong of the Joseon Dynasty. *Publications of the Korean Astronomical Society*, 38(1), 1–12.
Sezgin, F., 2010. *Science and Technology in Islam II (Catalogue of the Collection of Instruments of the Institute for the History of Arabic and Islamic Sciences),* Transl. Sarma, R., and Sarma, S.R. Frankfurt am Main, Institut für Geschichte der Arabisch-Islamischen Wissenschaften. Pp.151–153.
Yun, Y.H., Mihn, B.-H., and Kim, S.H., 2023. Characteristics and manufacturing technology of the Angbuilgu treasure with plate pillars decorated with a dragon in clouds. *Korean Journal of Cultural Heritage Studies*, 56(4), 24–37.

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