

Meteorite Records in Korean History*

AHN Sang-Hyeon†

Introduction

Meteorites are pieces of celestial bodies that fall from space to earth. They contain precious information with which we can investigate the origins of the solar system. Meteorites are frequently found in the Antarctic. Meteorite *falls* are gathered from strewnfields after people have seen them fall from the sky. Meteorites that were collected without observation of the fall are called *finds*. More than 1,100 documented falls are listed in databases such as Meteoritical Bulletin Database,¹ the Meteorite Catalogue Database at the Natural History Museum,² and MetBase.³ Approximately six meteorite falls are reported each year. For some of these falls, we can calculate their orbits to determine their origin. Several automatic devices are now used to

Received May 8, 2019; Reviewed July 23, 2019; Accepted July 27, 2019.

DOI: <http://dx.doi.org/10.36092/KJHS.2019.41.2.169>

* This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (NRF-2018R1D1A1B07050035).

† Center for Theoretical Astronomy, Korea Astronomy and Space Science Institute, sha@kasi.re.kr

¹ The Meteoritical Bulletin was first published in 1957 in Moscow. The Meteoritical Bulletin Database is a searchable electronic resource that contains information about all known meteorites, and mirrors the information on new meteorites published in the Meteoritical Bulletin. The website is managed by the Meteoritical Society. See, <https://www.lpi.usra.edu/meteor/> (accessed on May 7, 2019)

² The Meteorite Catalogues had been published in paperback, until it became an e-catalogue that is managed by the Natural History Museum in London. Data for all meteorites reported up to June 2002 are included. See, <http://www.nhm.ac.uk/our-science/data/metcat/search/> (accessed on May 7, 2019)

³ MetBase is a meteorite information database and a bibliography of meteorites, tailored to the needs of both meteorite collection curators and researchers working in the field of meteoritics, impact cratering research, or planetary geology/space science. See, <http://www.metbase.org/content/introduction> (accessed on May 7, 2019)

monitor asteroids that have a high probability of landing on Earth. However, since those asteroids are small in size and low in albedo, these devices can detect at most three meter-class asteroids roughly one day before impact. For example, a meteorite fall on 7 October 2008 in the Nubian desert (asteroid 2008 TC₃), was detected 20 hours in advance.⁴ On 2 January 2014, asteroid 2014 AA was detected 21 hours before impact,⁵ and on 2 June 2018, asteroid 2018 LA was detected eight hours before impact.

One of the best examples of a fall is an asteroid that landed near the Russian city of Chelyabinsk on 15 February 2013 at 09:15 local time. It was the largest impact on Earth since the Tunguska event of 1908.⁶ Thanks to dashboard cameras, infra-sound measurements, and satellites, we can estimate the mass and orbit of pre-impact asteroids. Chelyabinsk meteorites are LL5 chondrites from the main asteroid belt between Mars and Jupiter.⁷ Chelyabinsk meteorites show typical features: a streak of intense light and a luminous trail, a sonic boom, and meteorites of various sizes in the strewnfield. Such phenomena were so unusual in ancient times that people documented them.

Ancient Chinese astrology described meteors and fireballs as “falling stars” (星隕), the fifth entry on the list of miscellaneous astronomical events (星雜變) in the “Tianwenzhi” 天文志 (Treatise of Astronomy) in *Suishu* 隋書 (Book of the Sui).

[Astrological Interpretation] If a big star falls down, [it implies that] the *yang* loses its proper position, and so it is a bud of disaster. It is also said, “If a large number of stars fall down, people shall lose their proper positions. In general, the state on which a star fall shall change the regime.” It is also said, “The place, on which a star falls, shall be a battlefield, and the world shall be in disorder. The potency will be valid for three years.”⁸

⁴ Peter Jenniskens et al., “The Impact and Recovery of Asteroid 2008 TC₃,” *Nature* 458 (2009), 485-488; David Farnocchia et al., “The Impact Trajectory of Asteroid 2008 TC₃,” *Icarus* 294 (2017), 218-226.

⁵ David Farnocchia et al., “The Trajectory and Atmospheric Impact of Asteroid 2014 AA,” *Icarus* 274 (2016), 327-333.

⁶ Olga P. Popova et al., “Chelyabinsk Airburst, Damage Assessment, Meteorite Recovery, and Characterization,” *Science* 342 (2013), 1069-1073.

⁷ Peter Jenniskens et al., “Radar-Enabled Recovery of the Sutter’s Mill Meteorite, a Carbonaceous Chondrite Regolith Breccia,” *Science* 338 (2012), 1583-1587.

⁸ *Suishu* 隋書, juan 20, “Tianwenzhi” 天文志: 大星隕下, 陽失其位, 災害之萌也。又曰: 衆星墜, 人失其所也。凡星所墜, 國易政。又曰: 星墜, 當其下有戰場, 天下亂, 期三年。

[Meteor outburst and its astrological implications] It is also said, “Stars fall like a rain, which means: the power of an emperor is weak while feudal lords will do great efforts to take power, and so the five counts will take power by turns to become a leading power. The majority will defeat the minority, and the big country will annex the small one.” It is also said, “That stars are attached to or detached from the sky can be compared to that people attached to or detached from the ruler. If the ruler loses his duty and relaxes discipline, then the ordinary people will betray and leave the ruler. Thus, it happens as an omen that stars betray the sky and fall down.”⁹

[Meteorites] If a star falls to become a bird or an animal, there shall be a military disaster in the state. If a star falls to become a flying insect, the world shall perish. If a star falls to become gold or iron, a great war shall break out. If a star falls to become soil, there shall be a great flood. If a star falls to become vegetation, the ruler of the kingdom shall die and a war shall break out. If a star falls to become sand, a war shall break out and the ruler of the state shall die. If a star falls to become a human being who talks, being good or evil will coincide with what it is said. It is also said, “If a star falls to become a dragon, there shall be great mourning in the country.”¹⁰

In *Chunqiu daquan* 春秋大全, we find Wu Cheng’s 吳澄 (1249-1333) commentary on a sentence comparing the stars to falling like rain (星隕如雨): “[*Xingyun* 星隕 is that] Stars fall from the sky and disappear in the middle of the sky. However, they do not reach the ground. Here ‘like a rain’ describes that they are numerous and thus uncountable.”¹¹ While his commentary faithfully explain the phenomenon, other Neo-Confucians of the Song and Yuan dynasties tried to explain such phenomena as thunder, thunderbolts, lightning-induced wildfires, and meteorites by introducing changes of *qi* 氣: “The thunder is the righteous *qi* (義氣) between heaven and earth. If a person does evil and (the righteous *qi*) timely senses with him, then a thunder will hit on him. The so-called fire (火) [of the lightning] is a natural consequence of collisions of *qi*. The so-called stone-axe (石斧) is a stone

⁹ Ibid., 又曰: 星隕如雨, 天子微, 諸侯力政, 五伯代興, 更爲盟主; 衆暴寡, 大并小。又曰: 星辰附離天, 猶庶人附離王者也。王者失道, 綱紀廢, 下將畔去。故星畔天而隕, 以見其象。

¹⁰ Ibid., 國有兵凶, 則星墜爲鳥獸; 天下將亡, 則星墜爲飛蟲; 天下大兵, 則星墜爲金鐵; 天下有水, 則星墜爲土; 國主亡, 有兵, 則星墜爲草木; 兵起, 國主亡, 則星墜爲沙; 星墜, 爲人而言者, 善惡如其言; 又曰: 國有大喪, 則星墜爲龍。

¹¹ *Chunqiu daquan* 春秋大全, juan 7, “Zhuanggong shang” 莊公 上: 恒星者, 列星也。如雨者, 言衆也。[……臨川吳氏曰: 隕, 謂自天而隕, 沒於半空, 而不至地; 如雨, 言衆多, 不可爲數也。]

made of *qi* that falls down (from the sky). Falling stars are also the same. As for the so-called letters engraved on it, there are no such reasons.”¹²

Falling stars were usually interpreted as bad omens. For this reason, meteors, meteor outbursts, and meteorites were observed and documented. Compared to other records, those of meteorites are rare, but we can find them in East Asian historical chronicles. For example, 365 records of meteorite appear in the Chinese historical literature through the end of the Qing dynasty (1636-1912).¹³ Only some of the meteorites have been preserved, and those were compiled by Bian and subsequently by Chen and Wang.¹⁴ Yang, Xuan, and Li analyzed 2,000-year data to obtain the frequency and spatial distribution of ancient meteorite falls in China.¹⁵ In 1988, astronomical records in Chinese history were compiled as *Zhongguo gudai tianxiang jilu zongji* 中國古代天象記錄總集 (Collection of Astronomical Records in Ancient China). The section on meteorites was compiled by He Ruiguang 何銳光 and Xia Xiaohé 夏曉和.¹⁶ Yau, Weissman, and Yeomans noted that 35 falls in China are listed in the *Catalogue of Meteorites*, edited by Graham, Bevan, and Hutchison. There are also 32 finds from A.D. 1920 to 1980.¹⁷ Since the *Catalogue* did not include a considerable number of meteorite falls throughout Chinese history, they compiled a list of meteorite falls from the catalogues written by Chen, Xuan and Xia.¹⁸ Nagatoshi revisited the meteorite records in local gazettes to complement the

¹² *Xingli Daquanshu* 性理大全書 (Great Compendium of Nature and Principle), juan 27, Liqi 理氣 2, “Leidian” 雷電 (Thunder and Lightning): 雷霆是天地間義氣。人爲不善，又適與之感會，則雷震之。有所謂火者，氣之擊搏，自有火生也。有所謂石斧者，氣之墜則爲石，星隕亦然。若所謂書字，則無是理。

¹³ He Ruiguang and Xia Xiaohé, “Studies of Ancient Meteors in China,” *Geochimica* 4 (1982), 412.

¹⁴ Bian Depei, “Chinese Meteorites,” *Meteoritics* 16:2 (1981), 115-128; Chen Yongheng and Wang Daode, “An Update of a Catalog of Chinese Meteorites,” *Meteoritics* 29 (1994), 886-890.

¹⁵ Yang W., Xuan R., and Li L., “Frequency and geographical distribution of ancient meteorite falling in China,” *Geochimica* 1 (1983), 52-61.

¹⁶ He Ruiguang and Xia Xiaohé, “Yunshi” 隕石: Zhuang Weifeng et al. eds., *Zhongguo gudai tianxiang jilu zongji* 中國古代天象記錄總集 (Nanjing: Jiangsu kexuejishu chubanshe, 1988), 63-105.

¹⁷ Kevin Yau, Paul Weissman, and Donald Yeomans, “Meteorite Falls in China and Some Related Human Casualty Events,” *Meteoritics* 29 (1994), 864-871; A. L. Graham, Robert Hutchison, and A. W. R. Bevan, *Catalogue of Meteorites: with Special Reference to Those Represented in the Collection of the British Museum* (Tucson: University of Arizona Press, 1985).

¹⁸ Chen Zungui 陳遵妣, *Zhongguo tianwenxueshi* 中國天文学史, Vol. 3 (Shanghai: Shanghai renmin chubanshe, 1984); He Ruiguang and Xia Xiaohé, “Yunshi.”

list.¹⁹ However, the astronomical records in local gazettes often contain errors in date and inaccurate descriptions.

There are no similar compilations for Korean meteorites. Only an incomplete description of meteorite falls in Korean history was given in section 2 of Hinse et al.²⁰ We thus need a more complete list. In most cases, meteorites have not been preserved, so there are no surviving samples. We therefore have to rely on textual descriptions. It is also well known that in pre-modern Korea, most astronomical records were kept in classical Chinese, making meticulous translation important. This paper offers a complete list of meteorite falls in Korean history. We also have carefully translated the historical materials in the appendix. We use this data to conduct physical analyses to classify some of the meteorites.

Meteorites in Korean History

(1) The Three Kingdoms Era (57 B.C. – A.D. 935)

The earliest period of Korean history is known as the Three Kingdoms Era. Most of the astronomical records from this era are preserved in *Samguksagi* 三國史記 (History of the Three Kingdoms) edited by Kim Bu-Sik et al. in the Goryeo dynasty, based on primary sources. There are records of meteors, fireballs (*Cheongu-seong* 天狗星, meaning heavenly dog stars), and meteor outbursts in *Samguksagi*, but no records of meteorite recovery. According to the treatises in *Shiji* 史記 and *Songshi* 宋史, *Cheongu-seong* looks like a big fireball, sometimes with sound and sometimes following a meteorite.²¹ However, if there is no obvious description of a recovered meteorite, we cannot claim that it is a meteorite record. For this reason, we do not regard the *Cheongu-seong* records in the *Samguksagi* as meteorite records if there are no obvious descriptions of recovery.

One interesting case came in the fifth month of the thirtieth year in the reign of King Biryu of Baekje 百濟 Kingdom (A.D. 333), which is reported by three sentences: “(1) a star fell. (2) a fire broke out in the palace, (3) and successively burnt

¹⁹ Nagatoshi Nogami, “Supplemental Ancient Chinese Meteor, Meteorite Fall and Comet Records with *Zhongguo gudai tianxiang jilu zongji* (1),” *Highlight of Astronomy* 16 (2012), 164.

²⁰ Tobias C. Hinse et al., “Proto-type Installation of a Double-station System for the Optical-video-detection and Orbital Characterization of a Meteor/Fireball in South Korea,” *Publications of The Korean Astronomical Society* 32:3 (2017), 381-403.

²¹ *Shiji* 史記, Tianguanshu 天官書 5, “Tianguou”天狗 resembles a big *Benxing* 奔星 (a runaway star) with sound. Where it falls seems the place on which a dog-like thing falls. Watching it, it looks like a fire flame that seems to reach to the sky. (天狗, 狀如大奔星, 有聲。其下止地, 類狗所墮及, 望之如火光炎炎衝天。); *Songshi* 宋史, Tianwenzhi 天文志 5, “Liuxing” 流星: The big meteor is called *Benxing*. If it falls at night, it is called a *Tianguou*. Its wickedness is huge (流星之大者為奔星, 夜隕而為天狗, 厥妖大).

people's houses down."²² There seems to be a certain causality between the star's fall and fire in the palace, but there are no conjunctions or adverbs that clarify the causality. Moreover, it is not true that a meteorite fall causes fire on the ground.²³ For this reason, we do not consider these records as meteorite falls.²⁴

Fireballs were regarded as bad omens, so the sudden appearances of fireballs would change military plans. We have at least five cases: (1) the retreat of Nangnang 樂浪 from Silla 新羅 in A.D. 14,²⁵ (2) Baekje's halted advance on Goguryeo 高句麗 in A.D. 398,²⁶ (3) Tang's 唐 victory over Goguryeo in 645,²⁷ (4) Kim Yusin's 金庾信 crushing of rebellions in 647,²⁸ and (5) Goguryeo's retreat from Silla in 661.²⁹ We can find records of the incidents that were influenced by meteorite falls.³⁰ However, unfortunately, the examples listed above were not meteorites but fireballs.

(2) Meteorites during the Goryeo Dynasty (918-1392)

As mentioned, *Cheongu-seong* 天狗星 is a fireball. However, not all fireballs result in the recovery of meteorites. In addition, rockslides and meteorite falls are usually described by the same Chinese letters or "*unseok* 隕石/*seogun* 石隕." Hence the two can be confused. Thus, we have to be painstaking in collecting astronomical records that are obviously about the recovery of meteorites.

²² *Samguksagi* 三國史記, gwon 24, "Baekje bongi" 百濟本紀, the thirtieth reign period of King Biryu 比流: 夏, 五月, 星隕, 王宮火, 連燒民戶.

²³ The outbreak of a fire in the palace following a fireball in A.D. 1283 is thought to have been a secondary effect.

²⁴ In general, meteors appear at 70-120 km altitude. A bright fireball can reach an altitude of 30 km. Some asteroids with the size of several tens of meters can reach the altitude of 15 km. After that altitude, the asteroids experience a shock-induced explosion and do dark flight. The fragments scatter on sprenfields.

²⁵ *Samguksagi* 三國史記, gwon 1, "Silla bongi" 新羅本紀, the eleventh reign period of Namhae Chachawung 南海 次次雄: "During the night a star fell on the thief's camp, and they were so frightened that they retreated." (夜有流星墜於賊營, 衆懼而退.)

²⁶ *Samguksagi*, gwon 25, "Baekje bongi," the eighth month of the seventh reign period of King Asin 阿莘: In the night a big star fell on the camp with a sound. The king disliked it so much that he stopped the campaign. (其夜大星落營中, 有聲. 王甚惡之, 乃止.)

²⁷ *Samguksagi*, gwon 21, "Goguryeo bongi" 高句麗本紀, the fourth reign year of King Bojang 寶藏.

²⁸ *Samguksagi*, gwon 41, "Yeoljeon" 列傳, Kim Yusin 金庾信, the fifty-sixth year in the reign of Queen Seondeok.

²⁹ *Samguksagi*, gwon 5, "Silla bongi," the eighth year in the reign of King Taejong muyeolwang, 太宗武烈王.

³⁰ Yau, Weissman, and Yeomans, "Meteorite Falls in China" (cit. no. 17).

We first search the meteorite records one by one in the “Cheonmunji” 天文志 (Treatise of Astronomy) and the “Ohaengji” 五行志 (Treatise of Five Phases) in *Goryeosa* 高麗史. We then crosscheck them against the historical records in the “Chronology” chapters (sega 世家) of *Goryeosa* and in *Goryeosa jeoryo* 高麗史節要. We also search keywords such as 隕石, 石隕, 有物, ‘隕+石’, ‘石+落’, ‘石+墜’ in the website of these chronicles.³¹ The search is complemented by performing keyword searches for the anthologies in the website of Korean classics with the same keywords,³² and also by making keyword searches in the chapter of astronomical records in *Jeungbo munheon bigo* 增補文獻備考. However, the “Treatise of Astronomy” and “Treatise of Five Phases” of *Goryeosa* suffice for collecting complete records, and no records other than those found in the two Treatises are found in the other books.

Goryeosa and *Goryeosa jeoryo* were compiled by historians of the Joseon dynasty, based upon the primary sources called *Goryeo sillok* 高麗實錄, which had been preserved in the palace until the Japanese invasion in 1592 when the historical materials were destroyed with the palace of the Joseon dynasty. The two chronicles are thought to be authentic, because King Sejong the Great 世宗大王 ordered the editors not to arbitrarily delete or modify terms or sentences in *Goryeo sillok*.³³ It is also noteworthy that the former 100 years part of the original *Goryeo sillok* was burnt during the Kitanese invasion to Goryeo in 1010. Soon after that, the *Sillok* was reconstructed from the remains. Hence, although the Goryeo dynasty was established in 918, astronomical records predating the eleventh century are rare.

We were able to collect six cases of meteorite falls in the Goryeo period. One controversial case is the meteorite that fell in the tenth year in the reign of the emperor Munjong. This record is the same as that of the eleventh reign year of same emperor. Although their sexagenary dates are different, the numeric dates in lunar calendar, converted from the sexagenary dates, are the same. It is therefore possible that there had been only the numeric dates in the original sources of the records and that the editors of the history book converted them into sexagenary ones. Since a more detailed description only for the second event appears in *Goryeosa jeoryo*, we may think that the record of the eleventh reign year is correct and the other was a mistake. Thus, we collect only the record of the eleventh reign year as independent

³¹ <http://db.history.go.kr/>

³² <http://db.itkc.or.kr/>

³³ The former editor in chief, Jeong Do-Jeon 鄭道傳, deleted the calamity records when he first edited the *Goryeosa*, but King Sejong permitted the servants to include bad omens as well in order to deliver exact facts and give lessons to the descendants [*Sejong sillok*, the twenty-third day, the second month in 1420]. The posthumous names were only permitted to the emperors, but the Goryeo dynasty used those names because the Goryeo people thought they lived in an empire. Sejong did not allow to delete these, and he ordered to just adopt what was written in *Goryeo sillok* [*Sejong sillok*, the twenty-ninth day, the twelfth month in 1423].

records. The summarized records of meteorites during the Goryeo dynasty are presented in Table 1, and we also present the complete set of records translated into English in the appendix.

One record of a meteorite from 1070, says, “In Daegu, a star fell to the ground and became a stone.”³⁴ This exemplifies the ancient notion that meteorites originated in the sky. There was another meteorite fall in 1294. “In Nisan-hyeon, a meteorite fell. Its material seemed to be a jade and its shape resembled a chicken egg.”³⁵ We can therefore infer that the ancient people knew that the meteorites are cosmic objects, and even that they were once stars. We also note that in many cases the meteorite falls were accompanied by thunderous noise, which must have been a sonic boom.

The solid circles in Figure 1 show the spatial distribution of meteorite falls during the Goryeo dynasty. Note that the borderlines vary. We expect a random distribution if the meteorite falls follow a Poisson process. As expected, there appears to be no particular concentration. The meteorites that fell during this period have not been preserved, and the records are neither detailed nor quantitative. Thus, we cannot obtain complete physical information from the data.

Table 1. Historical Records of Meteorites Collected from the Korean Chronicles of the Goryeo and Joseon Dynasties. Dates are given in the lunar calendar, and the dates in parentheses are either in the Julian or the Gregorian calendar. The calendar conversions were made in accordance with the table by Han Bo-Sik.³⁶ The observing sites are given by the names in the original text, by current names, and by longitudes and latitudes.

No.	Lunar date (Julian date)	Place (in old names)	Long. (°E)	Lat. (°N)
Current location of the place where the meteorite fell.				
Meteorite records				
Goryeo (918 ~ 1392)				
1.	1056.01.18 (6 Feb 1056)	Hwangju	125.78	38.67
Hwangju-eup, Hwangju-gun, Hwanghaebuk-do				
A stone fell with a thunderous noise.				

³⁴ *Goryeosa* 高麗史, gwon 8, *Sega* 世家, the twenty-fourth year in the reign of Emperor Munjong 文宗.

³⁵ *Goryeosa* 高麗史, gwon 54, *Ohaengji* 五行志, Metal (Geum 金).

³⁶ Han Bo-sik, *Hanguk nyeonryeok daejeon* 韓國年曆大典 (Gyeongsan: Yeongnam University Press, 1987).

2.	1057.01.18. (24 Feb 1057)	Hwangju	125.78	38.67
Hwangju-eup, Hwangju-gun, Hwanghaebuk-do A stone fell with a thunderous noise. The provincial governor offered it to the central court, but it was returned to him.				
3.	1070.01.08. (21 Feb 1070)	Daegu-hyeon	128.59	35.88
Gyeongsang Gamyong Park, Pojeong-dong, Daegu A star fell, and changed into a stone.				
4.	1230.01.29. (13 Feb 1230)	Jungwon-bu	127.94	36.97
Seongnae-dong, Chungju-si, Chungcheongbuk-do Two masses of stone fell with a thunderous noise.				
5.	1230.07.06. (15 Aug 1230)	Tongjin-hyeon	126.55	37.72
Wolgod-myeon office, Bucheon-si, Gyeonggi-do A stone fell on Tongjin-hyeon of Annam-bu.				
6.	1294.03. (28 Mar–26 Apr)	Nisan-hyeon	127.13	36.28
Eumnae-ri, Noseong-myeon, Nonsan-si, Chungcheongnam-do A stone fell. It has a jade-like property, and its shape was like a chicken egg.				
7.	1308.02.03. (25 Feb 1308)	Jangju	127.12	38.07
Gomun-ri, Yeoncheon-eup, Yeoncheon-gun, Gyeonggi-do A stone fell with a thunderous noise.				
Joseon (1392 ~ 1910)				
1.	1423.10.01. (3 Nov 1423)	Gangeum-hyeon	126.45	38.07
Gyejeong-ni, Godong-myeon, Geumcheon-gun, Hwanghae-do A stone fell with a thunderous noise.				
2.	1452.02.16. (7 Mar 1452)	Yongjin-hyeon	127.45	39.15

Wonsan-si, Gangwon-do A fireball fell, and a pit of 31.5 <i>ja</i> circumference was formed.³⁷				
3.	1492.04.01. (27 Apr 1492)	Jin-ju	128.11	35.18
Jinju-si, Gyeongsangnam-do A stone fell and was embedded deep in the ground. Excavated from the pit, its color was like those of either a <i>noeseol</i> or a <i>bongnyeong</i>. When scratched with a nail, its powder fell off.				
4.	1495.02.21. (17 Mar 1495)	Yeongchun-hyeon	128.49	37.08
Sang-ni, Yeongchun-myeon, Danyang-gun, Chungcheongbuk-do During daytime, a brassware-like thing, red like a fire, fell from the sky. A thing resembling a light-yellowish chicken egg was recovered, as hard as a stone, and like a palm nut. When cut, its section showed many layers wrapping a core that resembled acorn, and it was black and smelled like dung.				
5.	1563.02.18. (12 Mar 1563)	Saneum-hyeon	127.88	35.41

³⁷ Here the Korean length units of *ja* and *chi* should be noted. One tenth of *ja* is called *chi* in Korea. Both length units correspond to the Chinese length units of *chi* 尺 and *cun* 寸, respectively. Roughly speaking, the Korean *ja* unit corresponds to the European foot unit. However, the absolute lengths for these units are different from one another. The Korean length unit was reconstructed during the era of King Sejong in accordance with the method defined in the Chinese classics, and was applied to everyday life during the Joseon dynasty. There were five kinds of the rulers whose scales were defined in the era of King Sejong. (1) *Hwangjong-cheok* 黃鐘尺 is a ruler with a tuning tube length scale to measure the proper lengths for the absolute pitch of wind instruments. (2) *Joryeogi-cheok* 造禮器尺 is a ruler with a length scale for measuring the proper sizes of royal ritual vessels. (3) *Yeongjo-cheok* 營造尺 is a ruler with a standard length scale for measuring the sizes for the royal buildings and castle walls during construction. (4) *Pobaek-cheok* 布帛尺 is a ruler with a standard length scale for measuring the length of fabrics in markets. (5) *Ju-cheok* 周尺 is a ruler corresponding to the *Zhou*-length unit that was thought to have been used in the early Chinese dynasty called *Zhou* 周. In order to determine the absolute scale of the *Ju-cheok*, King Sejong first reconstructed the *Hwangjong-cheok* in accordance with the Chinese classics. In practice, the *Ju-cheok* played a role of the reference ruler for the other rulers. The *Ju-cheok* was bestowed to the provincial governors. Moreover, the other kinds of rulers except for *Ju-cheok*, by definition, cannot be used for measuring the size of pits. Thus, it seems reasonable to assume that the *Ju-cheok* was used when provincial governors measured the size of the pit to report to the central government.

Sancheong-eup, Sancheong-gun, Gyeongsangnam-do After a thunderous noise, a flying swallow-like object fell from the sky. When it fell to the ground, it made a noise and emitted smoke. Immediately after that, meteorites fell one after another. Those meteorites falling on rock shattered, while some meteorites falling on soft land made a pit 10 <i>ja</i> deep. When recovered, the meteorite's surface resembled rock with black surface and white interior. The bigger ones are as big as fist or a bowl for a monk's meal. The smaller ones were as small as a chestnut or a persimmon. The shattered one were similar to rice powder but its shape was indescribable further.				
6.	1633.07.17. (21 Aug 1633)	Gosan-hyeon	127.21	35.97
Gosan-myeon, Wanju-gun, Jeollabuk-do A star fell, and it was a black stone the size of a fist.				
7.	1635.07. (13 Aug~10 Sep)	Gwanseo	125.75	39.03
Gwanseo means the northwest part of the Korean peninsula called Pyeongan-do, the central city of which is Pyongyang in DPR Korea. A star resembling those in the Pleiades fell and became a rock as big as a dog's head.				
8.	1672.02.09. (7 Mar 1672)	Yeongcheon-gun	128.94	35.97
Yeongcheon-si, Gyeongsangbuk-do A stone was witnessed falling from the sky with thunderous noise in Jain-hyeon. It plunged by more than one <i>ja</i>. The stone was bluish dark, as big as a measuring-bucket or mal, and weighed 36 <i>geun</i>. It looked like a crouching tortoise that had scratches on its shell.				
9.	1689.06. (17 Jul ~ 14 Aug)	Bonghwa	128.74	36.89
Bonghwa-eup, Gyeongsangbuk-do A fist-sized stone fell from the sky. It was dark blue and weighed 4 <i>geun</i>.				
10.	1705.10.07. (22 Nov 1705)	Geumseong	127.42	38.25
Geumseong-myeon, Gimhwa-gun, Gangwon-do Afternoon, after a thunder, a star fell to become a stone.				

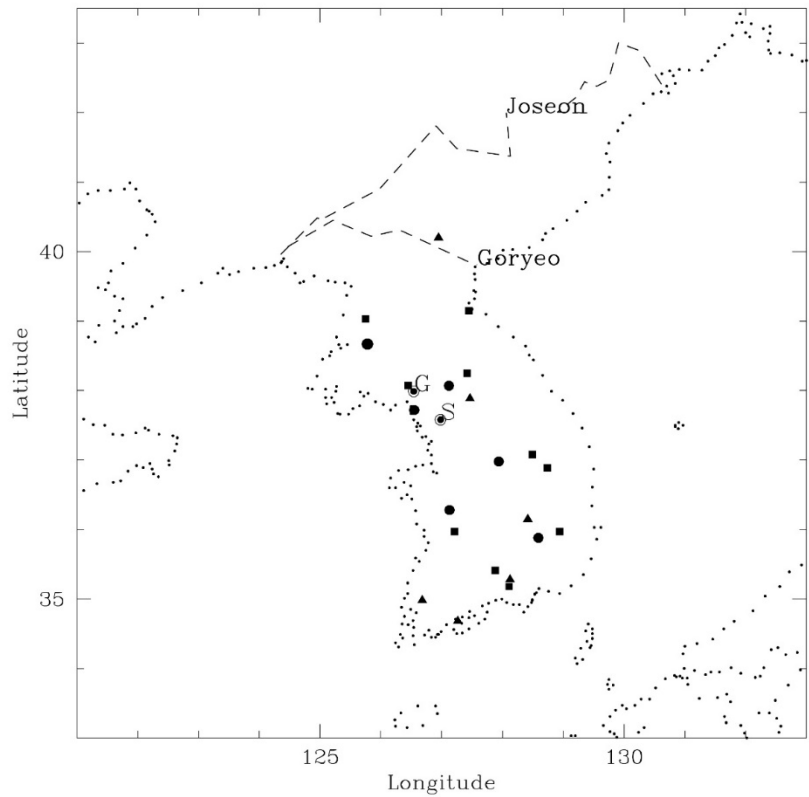


Figure 1. Spatial Distribution of Historical Meteorites in Korea. Solid circles represent the Goryeo data, squares represent the Joseon data, and triangles represent the modern recoveries. The capital city of the Goryeo dynasty was denoted a circled dot labelled G (Gaeseong). The capital city of the Joseon dynasty is represented by a circled dot labelled S (Seoul). The border lines for the two dynasties are drawn by dashed-lines.

(3) Meteorites during the Joseon dynasty and the Two Weighed Meteorites

We also performed keyword searches for the meteorite records in the websites of *Joseon wangjo sillok* 朝鮮王朝實錄 (The Annals of the Joseon Dynasty) and *Seungjeongwon ilgi* 承政院日記 (The Daily Records of Royal Secretariat of the Joseon Dynasty) with the same keywords to those used in searches for the Goryeo archives. The keyword searches with the same keywords are also performed for the

Comprehensive DB of the Korean Classics operated by the Institute for the Translation of Korean Classics.³⁸ They are also searched in *Jeungbo munheon bigo*.

We show the list of meteorite falls in Table 1, and the detailed translation of the raw texts are given in the Appendix. We note that the surface properties of some meteorites were described in the records, and that the formation of impact craters were reported in the records. We show the spatial distribution of these meteorite falls in Figure 1, where we find neither concentrations among themselves nor correlations with meteorites at other times.

In two instances, meteorites left craters. The meteorite of 1452 made an impact crater with a circumference of 31.5 *ja*. This corresponds to a radius of 5 *ja*. According to an investigation,³⁹ at that time one *ja* of *Jucheok* 周尺 was 20.3 cm. Thus, the radius of the impact crater was approximately one meter. The other impact crater was made by the meteorite of 1563. According to the record, the crater was 10 *ja* or 2 meters deep. We also have one case where showers of fragments were observed. The meteorites of 1563 were reported to have been of various sizes.

The size and mass of the meteorites in the list were measured. One of these meteorites fell at noon on the ninth day of the second month in the 13th year in the reign of King Hyeonjong (1672) in Yeongcheon-gun of Gyeongsang province. During the Joseon dynasty, the office of Yeongcheon-gun was located at the site of what is now the Yeongju Elementary School (128.83°E and 36.83°N) in the city of Yeongju in Republic of Korea.⁴⁰ According to the record, in Jain-hyeon located at the southern part of Yeongcheon-gun, after a thunderous noise, a meteorite fell from the sky and plunged approximately one *ja* (20.3 cm) into the ground. Bluish black in color, it looked like a crouching turtle with a scratched shell. The meteorite must have had a fusion crust. The meteorite was reported to be of the size of a one-*mal* vessel and to have weighed 36 *geun*. (A *mal* is roughly 6 liters,⁴¹ where one liter is equal to 1,000 cm³ in the cgs system of units.) The *geun* (630 grams) was used as a unit of weight in the Joseon dynasty.⁴² So the meteorite weighed 22,680 grams. Its bulk density, mass divided by volume, was approximately $\sim 4 \text{ g cm}^{-3}$ or a bit less.

Meteorites are classified in several ways. Here we will see the conventional classification scheme for meteorites reviewed by Weisberg, McCoy, and Krot.⁴³ As stated earlier, meteorites are classified as falls if they are witnessed and recovered;

³⁸ <http://db.itkc.or.kr/>

³⁹ Park Heungsu, *Hanjung doryanghyeong jedosa* 韓中度量衡制度史 (Seoul: Sungkyunkwan University Press, 1999), 613-640.

⁴⁰ The current geographical location for the previous names was identified by searching at the various Korean internet site, and its geographical coordinate was found in Google Earth.

⁴¹ Park, *Hanjung doryanghyeong jedosa*.

⁴² Park, *Hanjung doryanghyeong jedosa*.

⁴³ M. K. Weisberg, T. J. McCoy, and A. N. Krot, "Systematics and evaluation of meteorite classification," D. S. Lauretta and H. Y. McSween Jr. eds., *Meteorites and the Early Solar System II* (Tucson: University of Arizona Press, 2006), 19-52.

otherwise they are finds. Some meteorites are named after the locations from which they were recovered. We also classify meteorites according to their appearance and composition (stony, iron, stony-iron). Another professional classification is based on their mineralogical, petrographic, isotopic, and chemical properties. Chondrites are meteorites that include chondrules or small (1-2mm) spheres. Chondrites have solar abundances and most of them originate from asteroids. Achondrites are igneous rocks or breccia of igneous rock fragments. They show igneous or recrystallized textures in their cross-section. Thus, achondrites are thought to have originated from either a differentiated large asteroids or planetary bodies such as lunar and Martian meteorites. Some meteorites have igneous or recrystallized textures, but their chemical composition is closer to chondrites. These are known as primitive achondrites.

Although more sophisticated data, such as porosity and magnetic susceptibility, are needed to make a strong statement on the exact classification, bulk densities of a meteorites alone can be used to roughly classify the meteorites. The bulk densities for various groups of meteorites were measured by Britt and Consolmango et al., and Macke et al. (see Table 2).⁴⁴

As noted above, the bulk density of the meteorite of 1672 was $\sim 4 \text{ g cm}^{-3}$ or a bit less. Comparing this with the bulk densities in Table 2, we can see that the meteorite of 1672 must be either an EH or an EL enstatite meteorite. If we can estimate the porosity and/or magnetic susceptibility of the meteorite, we can classify the meteorite even more accurately. However, we do not know the whereabouts of this meteorite, and thus, it is impossible to obtain further physical information.

Another meteorite whose size and mass were measured was recovered in the sixth month of the 15th year of the reign on King Sukjong (1689). It was a fist-sized meteorite whose mass was 4 *geun*. We assume that an adult's fist has a radius of 5 cm, and 1 *geun* is equal to 630 grams. Thus, its bulk density is $\sim 5 \text{ g cm}^{-3}$, from which we can conclude that the meteorite must be a stony-iron meteorite including palasites and mesosiderites (see Table 2). The iron meteorites are ruled out, because they have a much higher bulk density of $7\sim 8 \text{ g cm}^{-3}$.

⁴⁴ D. T. Britt and G. J. Consolmango, "Stony Meteorite Porosities and Densities: A Review of the Data through 2001," *Meteoritics and Planetary Science* 38 (2003), 1161-1180; G. J. Consolmango, D. T. Britt, and R. J. Macke, "The Significance of Meteorite Density and Porosity," *Geochemistry* 68 (2008), 1-29; Robert J. Macke, Daniel T. Britt, and Guy J. Consolmango, "Density, Porosity, and Magnetic Susceptibility of Achondritic Meteorites," *Meteoritics and Planetary Science* 46 (2011), 311-326.

Table 2. Classification of Meteorites⁴⁵ and the Bulk Densities Measured for Various Kinds of Meteorites. There is no consensus on the terminology concerning the hierarchy of meteorite classification. But, for chondrites we use subgroups, groups, clans, and classes in accordance with the degree of relatedness. Those meteorites that are closely related are thought to have come from a single parent body, usually an asteroid. The bulk density measurements are given with the numbers in parentheses that denote the citations, where [1] means Britt and Consolmagno, [2] Consolmagno et al., [3] Macke et al.⁴⁶

	Class	Clan	Group	Bulk density (g cm ⁻³)
Chondrites	Carbonaceous chondrites (C)	CI	CI	1.6±0.03 [2]
		CM-CO	CM	2.25±0.08 [2]
			CO	3.03±0.19 [2]
		CV-CK	CVo	2.79±0.06 [2]
			CK	2.85±0.08 [2]
		CR	CR	3.1 [1]
	Ordinary chondrites (O)	H-L-LL ⁴⁷	H	3.42±0.18 [2]
			L	3.36±0.16 [2]
			LL	3.22±0.22 [2]
	Enstatite (E)	EH-EL 3.46±0.16 [2]	EH	3.72±0.02 [1]
			EL	3.55±0.10 [1]
Primitive Achondrites			Ureilites	3.05±0.22 [1] 3.14±0.22 [2] 3.22±0.2 [3]
			Brachinites	3.23±0.18 [2] 3.48±0.26 [3]
		ACA-LOD	Acapulcoite	3.42 (3.33~3.59) [3]

⁴⁵ M. K. Weisberg, T. J. McCoy, and A. N. Krot, "Systematics and Evaluation of Meteorite Classification."

⁴⁶ D. Britt and S. Consolmagno, "Stony Meteorite Porosities and Densities"; G. J. Consolmango, D. T. Britt, R. J. Macke, "The Significance of Meteorite Density and Porosity"; R. J. Macke, D. T. Britt, and G. J. Consolmango, "Density, Porosity, and Magnetic Susceptibility of Achondritic Meteorites."

⁴⁷ G. J. Consolmango, D. T. Britt, and R. J. Macke, "The Significance of Meteorite Density and Porosity."

			Lodranite	(3.24~3.82) [3]
		WIN-IAB-IIICD	Winonaite IAB IIICD	3.23±0.18 [2] 3.24±0.19 [3]
Achondrites		Vesta (asteroid) 2.9 (2.62~3.37)	Howardites Eucrites Diogenites	2.97±0.16 [2] 3.4±0.11 [3] 2.9±0.13 [2] 3.4±0.11 [3] 3.23±0.15 [2] 3.4±0.11 [3]
			Aubrites	3.12±0.15 [1] 2.90±0.31 [3]
			Angrite	3.18~3.24 [3]
			Pallasites (stony-iron meteorites)	4.76±0.10 [1]
			Mesosiderites (stony-iron meteorites)	4.25±0.02 [1]
			IC, IIAB, IIC, IID, IIE, IIIAB, IIIE, IIIF, IVA, IVB (iron meteorites)	7~8
		Moon		
		Mars ⁴⁸	Shergottite Nakhlite Chassignite Orthopyroxenite	3.03±0.18 [2] 3.01±0.14 [3] 3.15±0.07 [2] 3.11±0.13 [3] 3.46±0.02 [1] 3.4±0.11 [2] 3.48±0.08 [3]

48 I. M. Coulson, M. Beech, and W. Nie, “Physical Properties of Martian Meteorites: Porosity and Density Measurements,” *Meteoritics and Planetary Science* 42 (2007), 2043-2054.

Another notable event was recorded in an anthology of Ryu Huichun 柳希春 (1513-1577). According to his journal, in 1570 a stone with nine Chinese characters engraved on it fell from the sky. This was surely an unusual event. The stone must have been made of metal, because it reportedly clinked when shaken. However, since there is no additional information, we cannot understand the event scientifically. The engraved characters are to chant the longevity of the king or the country. This event reminds us of the sentences cited in the introduction of this paper from *Xingli daquan* 性理大全: “As for the so-called letters engraved on it, there are no such reasons (若所謂書字, 則無是理).” The stone might have been made by someone who wanted to flatter the king. This shows one of the notions held by pre-modern East Asians, but it cannot be included in the meteorite list.

On the ninth day of the ninth month in the third year of the reign of King Seonjo: A stone fell on Gongdeong-ni 孔德里 at the southwest of Seoul. The stone was smaller than the plowshare, and when it rocked, it clinked. There were three lines of letters written on it, which consist of nine Chinese letters read as follows: *cheong san gap su man se cheon ha seok* 青山甲壽萬世天下石. The letters did not reveal in bright places, but they appeared only in dark places. Yesterday it was shown to the scholars in the Royal Secretariat 承政院 and the Royal Academy 弘文館. They all told that it is a quite weird affair.⁴⁹

On the tenth day, the ninth month in the third year of the reign of King Seonjo: I saw the Official Gazette. Hanseong-bu reported, “On the fifteenth day of the eighth month, at noon, when it was cloudy and raining, a thing fell from the sky at the house of Chungsunwi 忠順衛 Kim Illye 金逸禮 living in Gongdeong-ni 孔德里 below the Yongsan 龍山. After hearing jingling sound, he went there and obtained a thing to see that it was a mass of a black stone. There were written letters at both sides. He thought that it is quite weird, and so he offered it to Hanseong-bu.” The king responded, “I read the report given by the magistrate of Hanseong-bu. The stone falling from the sky is sufficiently weird and absurd. What is worse is the letters on it. How is it reasonable? I cannot believe this”⁵⁰

⁴⁹ *Miamjip* 眉巖集, gwon 8, “Miam ilgi” 眉巖日記, the ninth day, ninth month of the third reign year of King Seonjo (1570): 初九日, 西南孔德里有隕石. 石比耜而小. 叩之有錚錚然之聲. 文有三行, 有青山甲壽萬歲天下石九字. 明處不見, 而陰處則現. 昨日承政院及玉堂皆取觀, 至爲怪異云.

⁵⁰ *Miamjip* 眉巖集, gwon 8, “Miam ilgi,” the tenth day, ninth month of the third reign year of King Seonjo (1570): 初十日, 見昨日朝報. 漢城府啓: 西部龍山下孔德里居, 忠順衛金逸禮家, 去八月十五日午時, 天陰灑雨, 有物自空而下. 鏗然有聲, 取見則黑石一片, 內外面有書字, 至爲怪異, 同石持來, 自部進告云云. 傳曰: 觀此漢城府入啓, 有石自空而下云者, 已爲怪誕, 而至於書字, 寧有是理, 未可信也.

(4) Meteorites in Modern Korea

In the first half of the twentieth century, only four meteorites were reported by the Japanese⁵¹: Unkoku (7 September 1924), Gyokukei (7 March 1930), Shohaku (earlier than 1938), and Duwun (23 November 1943). They are summarized in Table 3. The meteorites were given Japanese names by the Japanese people. Hence, based on the pronunciation and the coordinates of recovered places, we assume that Unkoku is present-day Ungok-dong, Naju-si, Jeollanam-do, and that Gyokukei of Keishohokudo is now Okgye-dong, Gumi-si, Gyeongsangbuk-do.

Table 3. Meteorite Falls Recovered in Modern Korea. The four meteorites recovered during the Japanese colonial period were given Japanese names.

No.	Name	Date of fall or find	Place	Classification	Mass
1.	Unkoku	7 Sep 1924 (fall)	Ungok-dong, Naju-si, Jeollanam-do 126°41'E, 34°59'N	Ord. chondrite	1,000 g
2.	Gyokukei	17 Mar 1930 (fall)	Okgye-dong, Gumi-si, Gyeongsangbuk-do 128°25'E, 36°9'N	Ord. chondrite	1,320 g
3.	Shohaku	1938 (find)	Sobaeng-ni, Daeheung-gun, Pyeonannam-do 126°57'E, 40°12'N	Iron	101 g
4.	Duwun	23 Nov 1943 (fall)	Duwon-myeon, Goheung- gun, Jeollanam-do 127°16'E, 34°41'N	L6 chondrite	2.12 kg
5.	Gapyeong	1999 (find)	Gapyeong-gun, Gyeonggi- do 127°28'E, 37°53'N	Iron (IAB-sLL)	180 kg
6.	<i>Jinju</i>	9 Mar 2014 (fall)	Jinju-si, Gyeongsangnam-do 128°07'E, 35°17'N	H5 chondrite	34 kg

⁵¹ Choi Byeon-Gak, Ahn Insoo, Lee Minseong, and Shin Hongja, “Thermal and Shock Metamorphic Episodes of the Duwun L6 Chondrite: Petrological Evidence,” *Geoscience Journal* 6:3 (2002), 161-167.

According to the *Meteoritical Bulletin* No. 12, Shohaku meteorite was found in Neien-gun, Heiannan-do, whose latitude is 40°19'N and longitude is 126°55'E.⁵² The geographical name was also given in Japanese. Heiannan-do is certainly Pyeongannam-do in Korean. Sohaku must be Sobaek in Korean. If we look for any place in Pyeongannam-do that has a name of Sobaek, we can only find Sobaeng-myeon, Yeongwon-gun, Pyeongannam-do that had been called as such before Korea's independence. The place was merged into Daeheung-gun in 1952. Yeongwon is pronounced Nei-en in Japanese, which is consistent with the name in the *Bulletin*. The place is now called Sobaeng-ni, Daeheung-gun, Pyeongannam-do, and its latitude is 40°12'N and longitude is 126°57'E, which agree with the coordinates given in the *Bulletin*.

We do not know where these three meteorites are. Only the Duwun meteorite has been preserved and is displayed in the geological museum of the Korea Institute of Geoscience and Mineral Resources in Daejeon. It was recovered in what is now Duwon-myeon, Goheung-gun, Jeollanam-do. The meteorite has a mass of 2.117 kg and classified as L6-type ordinary chondrite.⁵³

According to the *Meteoritical Bulletin* No. 103, Gapyeong meteorite is an iron meteorite of approximately 180 kg that was found at the mountain area near Gapyeong-gun, Gyeonggi-do, during the construction of the forest road in November 1999.⁵⁴ The owner of the meteorite sliced the surface of the iron and brought it to Seoul National University in 2005, where it was examined and confirmed as an iron meteorite. The owner cut the iron into five pieces (72.45 kg, 44.02 kg, 34.02 kg, 21.70 kg, 8.30 kg), and donated one of them (34.02 kg) to Seoul National University in July, 2014.

A recent meteorite fall is the Jinju meteorite, which was recovered after a fireball was observed in many places in Korea on 9 March 2014. Starting in the Suwon area at 20:04 (KST), the fireball traveled more than 300 km southwards. Many people in the southern part of the Korean peninsula heard the sonic boom. The fireball was recorded by numerous dashboard cameras, but those data are not accurate enough to determine its orbit. Four meteorites weighing 9 kg, 4.1 kg, 0.4 kg, and 20.5 kg were recovered in a few days after the fireball event within 5 km of the first recovering place in the Jinju area. The meteorite is classified as an H5 chondrite, and a detailed geochemical analysis was made by Nagao et al..⁵⁵

⁵² The original record is listed in *Meteoritical Bulletin* No. 12. We can search the records in the website <https://www.lpi.usra.edu/meteor/> by name.

⁵³ Ahn Insoo, "Petrology and Mineral Chemistry of Duwun Meteorite: Implication to Thermal and Shock Metamorphism," (Master thesis, Seoul National University, 2002); See also Choi et al., (cit. no. 51).

⁵⁴ Alex Ruzicka et al., "Meteoritical Bulletin No. 103," *Meteoritics and Planetary Science* 53 (2017), 2661. Available at: <https://doi.org/10.1111/maps.12888> (accessed on 24 October 2018).

⁵⁵ Nagao Keisuke et al., "Major Elements and Noble Gases of the Jinju (H5) Meteorite, an Observed Fall on March 9, 2014, in South Korea," *Geochemical Journal* 50 (2016), 315-325.

We show all meteorites in Figure 1 as solid triangles. Their spatial distribution shows no concentrations and no correlations with respect to the meteorites from other times.

Discussion

In this paper, we have collected historical records of meteorites out of the official chronicles in Korean history. The results are listed in Table 1, and the detailed translations of the raw historical texts are given in the appendix. We have no records of meteorite falls and finds from the Three Kingdoms era. The phenomena mentioned in the chronicles from this period are fireballs (*Cheongu-seong* or heavenly dog stars). Some records describe the influence of fireballs on human activities. Six meteorites were recovered during the Goryeo dynasty (918-1392), but the descriptions are rather simple. During the Joseon dynasty (1392-1910), there are ten records of meteorites. We have two cases of impact craters, one case of showers of fragments, and two cases of measuring the size and mass of the meteorites. The bulk densities are calculated from the measurements and compared with recent data, which indicate that the meteorite of 1672 might be an EH/EL enstatite meteorite and the meteorite of 1689 might be a stony-iron meteorite. The meteorites recovered in modern times are also listed in Table 3. The spatial distribution of the meteorites in Figure 1 shows no concentration. All the meteorites are falls, except for two meteorites from 1938 and 1999. The Gapyeong meteorite of 1999 is an iron meteorite of type IAB-SLL. We note that iron meteorites take much longer time to weather and are easier than other types of meteorites to identify as unusual. Most historical meteorites in Korean history were accompanied by a sonic boom. We anticipate that this work will be useful for future research.

Except for space exploration, most information on the universe has been obtained by observations, not from experiments. However, especially in ground-based astronomy, meteorites are unique materials that provide us with tangible information about the universe. In this sense, we are curious about what ancient people thought of meteorites. According to the astronomical records, ancient people conducted minute observation of meteorites, and sometimes cut them in half to see what they were made of. In addition, ancient Koreans knew that meteorites came from the sky. Surely they thought that stars that had fallen to the ground became stones or meteorites. They thought that fireballs and meteorites could be related to either the fire or the metals when they were interpreted in accordance with the five-phase theory. In earlier times, these phenomena were interpreted as astrological portents, and so the rites for the removal of bad luck were conducted by the court. In later times, when the neo-Confucianism became dominant, those phenomena came to be accounted in a rational way, while at the same time not losing its astrological meaning as a portent.

Appendix

I. Goryeo Dynasty

1. On *Sinmi*⁵⁶ (Xinwei #8) day (the eighteenth day) of the first month in the tenth year in the reign of Emperor Munjong (1056): A stone fell in Hwang-ju with a thunderous noise (文宗十年正月辛未, 隕石于黃州, 聲如雷; 文宗(丙申)十年春正月, 辛未, 隕石于黃州, 聲如雷.) [*Goryeosa* 高麗史, gwon 54, “Ohaengji” 五行志, Metal (*Geum* 金)]; *Goryeosa*, gwon 7, “Sega” 世家 the tenth year in the reign of Emperor Munjong 文宗]

1-1. On *Eulmi* (Yiwei #32) day (the eighteenth day) of the first month in the eleventh year in the reign of Emperor Munjong (1057): A stone fell in Hwang-ju with a thunderous noise ((文宗)十一年正月乙未, 隕石于黃州, 聲如雷; (丁酉 11 年 春正月) 乙未, 隕石于黃州, 聲如雷.) [*Goryeosa*, gwon 54, “Ohaengji” Metal”; *Goryeosa*, gwon 8, “Sega” the tenth year in the reign of Emperor Munjong]

1-2. On *Eulmi* day of the first month in the eleventh year in the reign of Emperor Munjong: A stone fell in Hwang-ju with a thunderous noise. The magistrate offered the stone to the central court. The minister of rites told, “Once there was such a meteorite fall in the Song state in the Chunqiu period of China. There was also star’s fall during the Qin dynasty (221-206 B.C.). Since the Jin dynasty (A.D. 265-420) and the Tang dynasty (A.D. 618-907), such events frequently happened. This is merely a usual phenomenon and does not relate with any calamity. Now he regards this as being a weird event to report on it, which seems to be an absurd behavior. I ask your majesty to send him to the concerned ministry and punish him.” The emperor agreed, and at last returned the stone. (乙未, 隕石于黃州, 聲如雷. 州上其石. 禮司奏曰, “昔, 宋有隕石, 秦有星墜. 晉唐以降, 比此有之, 此常事也, 不關災祥. 今以爲異而聞奏, 實爲妄舉. 請下有司, 罪之.” 制可, 遂還其石.) [*Goryeosa-jeoryo* 高麗史節要, gwon 5, The first month of the eleventh year in the reign of Emperor Munjong]

2. On *Gyeongja* (Gengzi #37) day (the eighth day) of the first month in the 24th year in the reign of Emperor Munjong (1070): A star fell in Daegu-hyeon, and changed into a stone. (文宗 24 年 1 月 庚子, 星隕于大丘縣, 化爲石; 春正月, 庚子, 星隕于大丘縣, 化爲石.) [*Goryeosa*, gwon 47, “Cheonmunji” 天文志; *Goryeosa*, gwon 8, “Sega,” the first month of the twenty-fourth year in the reign of Emperor Munjong]

⁵⁶ *Sinmi* is the eighth entry of the sexagenary cycle, *Xinwei* in Chinese.

3. On *Imjin* (*Renchen* #29) day (the twenty-ninth day) of the first month in the seventeenth year in the reign of Emperor Gojong (1230): Two clumps of stone fell in Jungwon-bu with a thunderous noise. ((高宗)十七年正月壬辰, 隕石于中原府, 二, 聲如雷.) [*Goryeosa*, gwon 54, “Ohaengji” Metal]

4. On *Eulmi* (*Yiwei* #32) day (the sixth day) of the seventh month in the seventh year in the reign of Emperor Gojong (A.D. 1230): A stone fell in Tongjin-hyeon of An-nam-bu. ((高宗 17 年) 七月乙未, 隕石于安南府通津縣.) [*Goryeosa*, gwon 8, “Ohaengi”]

5. In the third month of the twentieth year in the reign of King Chungnyeol (1294): A stone fell in Nisan-hyeon. The material resembled a jade, and its shape resembled a chicken egg. ((忠烈王)二十年三月, 隕石于尼山縣. 其質如玉, 形如雞子.) [*Goryeosa*, gwon 54, “Ohaengji” Metal]

6. On *Gyesa* (*Guisi* #30) day (the third day) of the second month of the thirty-fourth year in the reign of King Chungnyeol (1308): A stone fell in Jang-ju with a thunderous noise. ((忠烈王)三十四年二月癸巳, 隕石于漳州, 聲如雷.) [*Goryeosa*, gwon 54, “Ohaengji” Metal]

The following records are also considered to be relevant with meteorites due to the literal meaning of the reports described in classical Chinese, but in fact they were not meteorites. We presented these records here to avoid confusion.

1. On *Musin* (*Wushen* #45) day (the 24th day) of the fourth month (22 May in the Julian calendar) in the 9th year in the reign of King Chungnyeol (1283): During the night, there is a thing that were red like a fire, as large as one *mal* or a measuring bucket, and gradually spread to be as large as a sitting mat. It fell to the Sunchang Palace. Meteors fell successively one another. In the end a storm occurred. A fire broke out in the palace, and nothing left after being burnt out. ((忠烈王)九年四月戊申, 夜, 有物, 赤如火, 大如斗, 漸廣如席, 墜順昌宮, 流星相繼而隕. 既而風暴作, 火起宮中, 焚蕩無餘; (九年)夏四月, 戊申, 夜, 有物, 赤如火, 大如斗, 漸廣如席, 墜順昌宮, 流星相繼而隕, 既而風暴作, 火起宮中, 焚蕩無餘.) [*Goryeosa*, gwon 53, “Ohaengji” Fire (火 *Hwa*)”; *Goryeosa*, gwon 29, “Sega” the fourth month of the ninth year in the reign of King Chungnyeol]⁵⁷

⁵⁷ This record was written in the chapter of Fire, and it is certainly a fireball. Thus those people of the period thought that the fireballs were a sort of fire. These events are an example of reported incidents of human casualties resulting from fireballs.

2. On *Sinsa* (*Xinsi* #18) day of the ninth month of the fifteenth year in the reign of King Gongmin (1366): In the northwest direction was a thing, as red as blood, as large as a bamboo basket. It descended from the sky and fell at the boundary between Yeom-Ju and Bae-Ju. A white vapor traversed across the sky, which disappeared a little bit later. ((恭愍王)十五年九月, 辛巳, 西北有物, 赤如血, 大如簞, 自天而下, 隕于塩白州之境, 白氣射天, 良久乃散.) [*Goryeosa*, gwon 53, “Ohaengji” Fire]⁵⁸

3. On *Imo* (*Renwu* #19) day of the fifth month of the third year in the reign of Emperor *Deokjong* (1034): A stone fell from Mt. *Song’ak*. (德宗三年五月壬午, 隕石于松岳.) [*Goryeosa*, gwon 55, “Ohaengji” Earth (土 *To*)]; On *Byeong-O* (*Bingwu* #43) day of the second month of the twenty-fourth year in the reign of Emperor *Myeongjong* (1194): A stone fell from Mt. *Songak*. ((明宗)二十四年二月丙午, 隕石于松岳山.) [*Goryeosa*, gwon 55, “Ohaengji” Earth]⁵⁹

4. On *Gyeong-in* (*Gengyin* #27) day of the seventh month of the first year in the reign of Emperor *Jeongjong* (1035): A stone fell from the Jeok seok jeong peak of Mt. *Samgak*. (靖宗元年七月庚寅, 三角山積石頂, 有隕石.) [*Goryeosa*, gwon 55, “Ohaengji” Earth]⁶⁰

II. Joseon Dynasty

1. On *Musin* (*Wushen* #45) day (the first day) of the tenth month in the fifth year in the reign of King *Sejong* (1423): It was reported that a stone fell on the ground in Gangeum-hyeon of Hwanghae-do with a thunderous noise. Hence, officials of the central court were sent there to perform a rite to remove its disaster. (隕石于黃海道

⁵⁸ It certainly describes a fireball that left the smoke-like trail that had soon disappeared. There is no report on the recovery of meteorites, and so we cannot regard this as a meteorite record. We can think that the people at that times classified this kind of phenomena as fire-related events, because it was written in the Fire section.

⁵⁹ Here *Songak* 松嶽 is the name of a major mountain in the capital of the Goryeo dynasty. These two records describe an event by Chinese words ‘*yun shi* 隕石’ meaning a rock (*shi* 石) falling down (*yun* 隕) from a mountain, although the same words can be used to describe meteorites. These two records were written in the chapter of Earth among the five phases, which indicates the events are related with phenomena happening on lands. On the other hand, ‘*xing yun* 星隕’ means that a star (*xing* 星) fell down (*yun* 隕), which describes either a meteor/fireball or a meteorite.

⁶⁰ Here *Jeok seok* 積石 means the stacked rocks, and *Jeong* 頂 means a peak. Mt. *Samgak* 三角山 is still present in Seoul with the same name. This record is also written in the chapter of Earth, and so certainly it describes the falling down of a rock from a mountain.

江陰縣，聲如雷。遣官行解怪祭。) [*Sejong sillok* 世宗實錄, gwon 22, the first day, tenth month of the fifth year in the reign of King Sejong]

2. On *Gyeongjin* (*Gengchen* #27) day (the sixteenth day) of the second month in the second year in the reign of King Munjong (1452): A fireball fell on the ground in Yongjin-hyeon of Hamgil-do. The ground sank to form a pit of 31.5 *ja* circumference. The king sent officials there to perform a rite to remove its calamity. (咸吉道龍津縣，火塊墜地，陷周回三十一尺五寸。上命遣使，行解怪祭。) [*Munjong sillok* 文宗實錄, gwon 12, the sixteenth day, second month of the second year in the reign of King Munjong]⁶¹

3. On *Eulyu* (*Yiyu* #22) day (the sixteenth day) of the fifth month in the twenty-third year in the reign of King Seongjong (1492): Yi Geuk-Don 李克墩, the *Gyeong-sang-do* governor, reported rapidly: “On the first day of the fourth month, when it rained with lightning, a stone fell to Jin-ju, and a pit with a depth of one *ja* was formed on the ground. A picked soldier named Gang Gye-Son 姜繼孫 excavated it from the pit to get a meteorite. Its color was like a *noeseol*, and its shape was like a *bongryeong*. When being scratched with a nail, its powder fell off.” The king responded, “Do not send me the meteorite, because it cannot be comparable to the *noebu*.” (慶尙道觀察使李克墩馳啓曰：去四月初一日，雷雨，有石隕于晉州，陷入地一尺。正兵姜繼孫掘地得之，色如雷楔，狀如茯苓，以爪刮之，隨爪落屑。下書曰：非雷斧之比，其勿上送。)[*Seongjong sillok* 成宗實錄, gwon 265, the sixteenth day, fifth month of the twenty-third year in the reign of King Seongjong]⁶²

4. On *Eulhae* (*Yihai* #12) day (the twenty-first day) of the second month in the first year in the reign of King Yeonsan-gun (1495): During the daytime in Yeongchun-hyeon of Chungcheong-do, there was a thing that looked like a brassware and was as red as fire. It fell from the sky, and disappeared when it reached the ground. Its smoke ascended back to scatter. People went there to see a thing that resembled a chicken egg. Its color was light yellow, and it was as hard as stone. Its shape was like areca nut. Shaking it at ear, there was a noise as if there were something inside.

⁶¹ The term *hwagoe* 火塊 is used for describing the phenomenon. This term means a mass 塊 of fire 火, which literally means “fireball.” There is no report of recovery, but we regard this record as a meteorite event because it left a crater.

⁶² Here *noeseol* 雷楔 is a sort of mushroom growing on the root of bamboo. Its surface is black, while the interior is white. Its shape resembled a chestnut. *Bongryeong* 茯苓 is also a sort of mushroom growing on the root of pine tree. Its surface is dark brown with much wrinkles. Its shape is round. Here *noebu* 雷斧 is *leifu* in Chinese, and literally means a thunder-axe, which is thought to be either a relic of the Stone Age or a meteorite.

Jo Wi 曹偉, the governor of Chungcheong-do, had reported this, and he also had offered the thing to the central court. The king responded, “What is this? Let the minister of the secretariat inspect this.” The minister answered, “Once there were calamity phenomena that a star fell on the ground to become a stone. This time, observing the thing, it is not really a sort of meteorite. I think that the discoverer merely rattled off his absurd explanations. I am sure that it is related with neither good omen nor calamity. So, what about cutting it in half to investigate further?” The king ordered to cut the thing in half. It was wrapped with many layers, and at its core there was a thing that resembled acorn, which was black and stinky. (忠清道永春縣，晝有物如鎗瓶，其色如火，自天而下，至地而滅，餘光還上升，而散。就視之，形如雞卵，其色微黃，其堅如石，其狀類檳榔，當耳搖之，隱然有聲，如物在其中。觀察使曹偉，錄其事由，并其物上聞。傳曰：是何物也，示院相。院相等啓：古有隕星，爲石之異。今觀此物，固非隕石之類。意，得之者虛張怪誕之說耳，決非祥瑞之物，非關災異，剖視何如？命剖之，包有數重，內有物如橡實，色黑有穢臭。) [Yeonsangun ilgi 燕山君日記, gwon 3, the twenty-first day, second month of the first year in the reign of King Yeonsangun]

On Jeongmyo (Dingmao #4) day (the eighteenth day) of the second month in the eighteenth year in the reign of King Myeongjong (1563): At Bungni 北里 (North village) of Saneum-hyeon 山陰縣 in Gyeongsang-do 慶尙道, there was a greatly thunderous noise, which would be made when beating a drum and shooting arrows. People watched a thing falling from the sky, which looked like a flying swallow. People came closer to see something fluttering like a flying bird. When it fell on the ground, it produced a noise and smoke. Promptly another also fell. They went there to see that those falling on heaped rock were shattered, and that those falling on the thick and soft ground got embedded into the ground by approximately one *ja*. They resembled rock with black surface and white interior, which is not different from normal rocks. The bigger ones are as big as either a fist or a bowl that is used for a monk's meal, and the smaller ones are as small as either a chestnut or a persimmon. Shattered ones were similar to rice powder. They could be touched, but their appearance could not be described by name. [The historian comments: “A stone falling from the sky is an unusual calamity. Thinking over history, there were many calamity events of falling meteorites such as a meteorite having fallen on the Song 宋 state in the 16th year in the reign of the Duke Xi of the Lu state (魯僖公), and also a meteorite having fallen on Liangyuan 梁園 in the Jianzhao 建昭 first year of the emperor Yuan of the Han dynasty (漢元帝). Since the beginning of history, there have been a large number of meteorite calamities. Although it is not easy to specify its corresponding causes, we see that meteorites fell when political affairs came to be slack or decayed, or when the nation was waning and out of joint. Thus we cannot say that this calamity will not result in retribution. Is it time for the king to reflect on his faults to stop the disaster?”] (慶尙道山陰縣北里，雷聲大作，如擊鼓射矢之聲。人仰視之，如有物自天而下，狀如飛燕。近而見之，則翻作飛鳥之形，

落地有聲而烟生。俄而又落，就而見，墮於積石之上者破碎，落於厚地者入地一尺許，狀如石，外黑內白，與石無異。大者或如拳、或如鉢，小者如栗、或如柿。破碎者如米屑，可掬而不可名狀。[史臣曰：自天隕石，災異非常。考之於古，魯僖公十六年，隕石于宋，漢元帝建昭元年，隕石于梁園。歷代以來，隕石之變，亦多有之。雖不可的指爲某事之應，而或出於政事陵夷之日，或出於國家衰亂之時。變異之作，終不可謂無其應。豈非君上省愆弭災之時耶?)] [*Myeongjong sillok* 明宗實錄, gwon 29, the eighteenth day, second month of the eighteenth year in the reign of King Myeongjong]

On *Gapsin* (*Jiashen* #4) day (the sixth day) of the third month of the eighteenth year in the reign of King Myeongjong (1563): The king ordered to the Secretariats, “I read the report from the Gyeongsang-do governor. Meteorite falling from the sky is surely a weird calamity. Let him offer the meteorite quickly to the court, and let the officials in Hongmun-gwan do researches on it in history.” [Jeong Jong-yeong 鄭宗榮, the Gyeongsang-do governor, reported that on the 18th day of the second month a stone fell from the sky in *Saneum-hyeon*.] (傳于政院曰：觀慶尙監司書狀，則天之隕石，災異駭怪。其石斯速上送事，下諭，又令弘文館，考啓古事。[慶尙監司鄭宗榮書狀，二月十八日，山陰縣隕石。]) [*Myeongjong sillok* 明宗實錄, gwon 29, the sixth day, third month of the eighteenth year in the reign of King Myeongjong]

6. On *Jeongmi* (*Dingwei* #44) day (the seventeenth day) of the seventh month in the 11th year in the reign of King Injo (1633): A star fell on Gosan-hyeon. It was a fist-sized black stone. ((仁祖)十一年七月，丁未，星隕于高山縣，如一拳黑石。)[*Jeungbo munheon bigo* 增補文獻備考, vol. 7, *Sangwi go* 象緯考, “Yuun” 流隕 (Meteors and Meteorites)]

7. In the seventh month of the 13th year in the reign of King Injo (1635): A star resembling those in the Pleiades fell on the Gwanseo 關西 province, and became a rock as big as a dog's head. ((仁祖)十三年七月，旄頭星落于關西，化爲石，大如狗頭。)[*Jeungbo munheon bigo* 增補文獻備考, vol. 7, *Sangwi go* 象緯考, “Yuun” 流隕; Kim Siyang 金時讓 (1581-1643), *Hadam pajeongnok* 荷潭破寂錄 (Hadam's Miscellanea for Time-killing)]

8. A stone fell on Yeongcheon-gun: On the twenty-ninth day of the first month in the thirteenth year in the reign of King Hyeonjong (1672), around noon, when the sunlight was not seen due to the thin cloud in the sky, suddenly a noise was heard, which were at the first time like a roaring cannon and later like a weak thunder. It occurred in the northwest direction to reach southwest. After a while it stopped. Some local residents witnessed a stone falling from the sky at the border of Jain-hyeon that forms the southern part of this Yeongcheon-gun. The thunder rolled, and then it stopped just after the stone fell on the ground. It embedded into the ground

by more than one *ja*. The stone was as big as a measuring bucket called *mal*, and it weighed 36 *geun*. Its color was dark blue, and its shape was like a crouching tortoise on whose back had scratches made by animal's claws. (有石隕於永川郡：正月二十九日午時，天有微雲，不見日色，忽然天中有聲，始如大砲，終如隱雷。從西北方作，至于西南，良久乃止。本郡村氓，適於本郡南面慈仁縣境，見一石塊，從天而下，聲如雷動，墜地而後聲止，所墜之處，陷入尺許。其石大如斗，重三十六斤，色青黑，形如龜伏，上有痕如獸迹。) [*Hyeonjong sillok* 顯宗實錄, gwon 20, and *Hyeonjong gaesu sillok* 顯宗改修實錄, gwon 25, the ninth day, the second month in the thirteenth year in the reign of King Hyeonjong]

9. In the sixth month of the fifteenth year in the reign of King Sukjong (1689): A fist-sized stone fell from the sky in Bonghwa, its color was dark blue, and it weighed 4 *geun*. ((肅宗)十五年己巳六月，奉化有一拳石，自天墮落，色青黑，重四斤。) [*Yeolryeosil gisul* 燃藜室記述, Byeoljip 別集, gwon 15, “Cheonmun jeongo” 天文典故 Jaesang 災祥]

10. The Gangwon-do governor reported, “According to the report from the magistrate of Geumseong-hyeon, around *yu-si* 酉時 on the seventh day of the 10th month (in the thirty-first year in the reign of King Sukjong, 1705), after rolls of thunder were heard, a star fell to become a stone, which must be relevant with calamity. (江原監司書目，金城呈，以十月初七日酉時，天動後，星隕爲石，事係變異事。) [*Seungjeongwon ilgi* 承政院日記, vol. 427, the sixteenth day, eleventh month of the thirty-first year in the reign of King Sukjong]

Abstract

We collect meteorite records from Korean chronicles. The accounts began with a bright streak of light described as a falling star, followed by a thunderous noise. During the Three Kingdoms period (first century B.C. to 10th century A.D.), there are reports of fireballs but not of meteorite recovery. During the Goryeo dynasty (918-1392), we have six cases of meteorite recovery. There are ten records from the Joseon dynasty (1392-1910). We provide the geographical distribution of historical meteorite falls. In particular, the bulk density of the meteorite of 1672 is estimated to be $\sim 4 \text{ g cm}^{-3}$, corresponding to EH/EL enstatites, and that of A.D. 1689 has a bulk density of $\sim 5 \text{ g cm}^{-3}$, corresponding to stony-iron meteorites. The whereabouts of three of six meteorites from modern times are known. Only two meteorites of 1938 and 1999 among 17 meteorites are finds.

Keywords: meteorite, meteor, historical astronomy, Korean history.