A list of meteorite falls and their impact craters from ancient Chinese records (7^{th}–19^{th} century)

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Eighteen meteorite falls and their impact craters from ancient Chinese records before 1911, compiled in (Beijing Astronomical Observatory, 1988), are listed. Some of the reports gave no information of meteorite mass and crater diameter. However, by supplementary calculated mass from their volume, data characteristics and impacting behavior of the listed meteorites are discussed in detail.

1 Introduction

Locating meteorite impact craters is important for the study of the material property of meteorites, the aerodynamics of their fall and the geology of the fall site. But so far, no accounts of meteorite falls with craters larger than a few tens of meters in diameter have been identified. Craters of this size have therefore only been studied by detailed crater research. On the other hand, many eyewitness reports of meteorite falls forming smaller craters, around one meter of depth, have been recorded in Chinese chronicles. This article presents a table of events taken from Chinese records before 1911 with the date of fall, location, crater depth and the meteorites' mass. Afterwards, the impacting behavior of the meteorites is discussed by parameters in the records and supplementary calculated meteorites' masses.

2 A list of meteorite falls and their impact craters

The *Zhongguo gudai tianxiang jilu zongji* (Beijing Astronomical Observatory, 1988) is a Chinese chronicle in which many kinds of astronomical records like comets and solar eclipses have been collected. All events date before 1911, the end of the Ching dynasty. From among the many meteorite fall witness records, eighteen events which are mentioned together with their impact craters have been listed in Table 1.

Event numbers with a suffix -a, -b, -c refer to collected meteorite fragments. The dates are converted to the Gregorian calendar from the original lunar calendar. For event 2, only the year is known. Three events, numbers 6, 11 and 17 are only dated to the month or to a few days precisely. Two events only give the name of the province, because their fall sites have not been identified yet. The depth of the impact crater and the mass and volume of the collected meteorite have been converted from ancient Chinese weights and measures.

It is remarkable that none of the accounts of this survey indicate crater diameter information, whereas all of them did indicate the crater depth. Fragmented meteorites can be found at the same depth. In order to collect the meteorite, researchers may have had to dig the fragments up, requiring hard work. This could explain why the crater depth seems to be an important factor to record. For discussion, supplementary calculated masses are given to the records, assuming a density of 3.0 g/cm^3 for a stony meteorite.

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Nr	date of fall	site of fall	crater [cm]	mass [kg]	volume [l]	calc. mass
1	616, May 28	32 °5 N, 119 °6 E	590	–	295 + cmD	40.326 t
2	1064	31 °4 N, 119 °8 E	92	–	∼10 cmD	1.54 kg
3	1393, Jul 24	29 °8 N, 113 °9 E	155	–	?	–
4	1478, Jul 20	Shanxi	93	–	1.7	5.1 kg
5	1499, Jun 28	39 °4 N, 112 °4 E	218	–	?	–
6-a	1568, Mar 29–Apr 26	39 °8 N, 115 °9 E	31	–	1.8?	5–6 kg
6-b	1568, Mar 29–Apr 26	39 °8 N, 115 °9 E	–	1.72	∼10 cmD	1.54 kg
7	1570, Jan 12	33 °3 N, 116 °5 E	31	–	1.8?	5–6 kg
8	1594, Aug 1	32 °3 N, 105 °7 E	93	–	17	51 kg (?)
9	1600, Oct 3	Henan	62–93	5.97	–	–
10-a	1613, Sep 21	37 °2 N, 115 °8 E	310	28.65	–	–
10-b	1613, Sep 21	37 °2 N, 115 °8 E	–	4.18(5.97)	–	–
10-c	1613, Sep 21	37 °2 N, 115 °8 E	–	5.37	–	–
11	1614, May 9–Jun 6	35 °9 N, 115 °1 E	31	–	1.8?	5–6 kg
12	1657, Jun 16	23 °3 N, 116 °5 E	96	7.76	–	–
13-a	1675, May 12	30 °1 N, 119 °9 E	96	2.39+	–	–
13-b	1675, May 12	30 °1 N, 119 °9 E	96	2.39+	–	–
14	1681, Mar 9	22 °9 N, 115 °3 E	31	5.37	–	–
15	1709, Nov 10	33 °6 N, 119 °1 E	62	11.94+	–	–
16	1744, Jun 6	28 °5 N, 117 °9 E	62	–	∼5.2	15.6 kg
17	1812, Nov 14–Nov 24	28 °1 N, 120 °9 E	31	–	1.04	3.1 kg
18	1832, May 15	23 °8 N, 114 °1 E	62	1.2–1.8	–	–

Table 1 – Meteorite falls and their impact craters gathered from (Beijing Astronomical Observatory, 1988). The crater depth is given in cm, the meteorite mass in kg, and the volume in liter. A "+" in the mass column means "a little more than..."; "cmD" in the volume column indicates the recorded diameter of the meteorite in cm. Calculated masses are obtained by assuming a density of 3.0 g/cm^3 for a stony meteorite.

3 Discussion

Among the events listed, number 1 was the most heavy meteorite, the only one to weigh over a ton. The mass of the second and third deepest craters, events 3 and 5, are unknown. Event 3 is probably lighter than one could expect at first sight because the record tells it fell into a muddy rice field. Event 5 could have weighed a few hundred kilograms or heavier: it was described to be "as large as a small wheel".

Most of the listed meteorites weigh less than one ton, but we can assume that for some of these only a few fragments were recovered in the crater. Some reports mention a fragmentation during the fall through the atmosphere. This means that the mass indicated in the table does not always refer to the whole body of the original meteoroid.

With this information we see that the events 4, 13 and 18 indicate deeper craters than we could expect based on the mass of the meteorite. Especially event number 13, even though recorded as a metallic body, has a crater that is too deep to be formed by a meteorite of this mass.

Of course crater depth not only depends on the mass of the impacting body but also on factors such as the geology of the fall site, the climate at the time of impact and the state of the soil at the site, like a plantation, a forest, a pasture and so on. Regrettably, none of the listed records has more details of these factors.

Perhaps in the future we can retrieve some fragments from these sites that have remained hidden underground.

4 Conclusion

This article presents the records of eighteen meteorite falls and the impact craters they formed listed from Chinese records before 1911. Using data from the original records supplemented with the calculated meteorite mass, we found that most of the craters listed were around one meter depth and that the meteorite bodies weighed less than one ton. Based on the discussed relation between crater depth and meteorite mass, we conclude that it is possible that hidden meteorite fragments can be unearthed in the future.

References

Beijing Astronomical Observatory (1988). *Zhongguo gudai tianxiang jilu zongji (Comprehensive collection of records of celestial phenomena in ancient China)*. Nanjing: Jiangsu Science and Technology Press.