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Report

Introduction to the special issue of *Meteoritics & Planetary Science* on the Winchcombe meteorite

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Abstract–This issue of *Meteoritics & Planetary Science* celebrates the science of the Winchcombe meteorite, which fell to Earth on the 28th February 2021 close to the town of Winchcombe, Gloucestershire in the UK.

The Winchcombe meteorite is special as it is the first recovered UK meteorite fall in 30 years (Daly et al., 2021; O'Brien et al., 2022; Rowe, 2021) and the first to be recovered after the fireball was captured by different camera networks in the UK Fireball Alliance (https://www.ukfall.org.uk/); these include those from SCAMP (part of the FRIPON network), the UK Fireball Network (part of the Global Fireball Observatory), the UK Meteor Observation Network (UKMON), AllSky7 (see Figure 1a), NEMETODE, and the Global Meteor Network. The fireball entry was also captured on numerous dashboard and doorbell cameras and there were over 1000 eyewitness accounts from across the entire UK, as well as Ireland and northern Europe, with reports of a sonic boom in the local area (Gattacceca et al., 2022; King et al., 2022). The camera observations helped to define the bolide's speed of entry, fall line, and field search campaign, and has established Winchcombe's pre-atmospheric orbit from a primitive asteroid parent body (King et al., 2022, see also McMullan et al., 2023).

The meteorite arrived during a period of the UK's COVID-19 pandemic national lockdown, meaning that the recovery efforts (Figure 1b) had to be carefully managed by the UKFAll team (Daly et al., 2023; O'Brien et al., 2022; Russell et al., 2023). In the days, weeks, and months, after the fall, several stones were successfully recovered from local residents' driveways, fields, and roadsides. The main mass (319 g) and dusty material was recovered from the driveway of a family living in the west of the town of Winchcombe—a small crater was left in their driveway tarmac by the impact (O'Brien et al., 2022), which has now been extracted and preserved as a cultural object at the Natural History Museum, London (Figure 1e, BBC, 2021).

The Winchcombe meteorite (Figure 1c,d) is a heterogeneous CM ("Mighei-like") chondrite meteorite containing at least nine distinct lithologies (Suttle et al., 2023). The rapid recovery of the main mass within 12 h makes Winchcombe one of the freshest carbonaceous chondrite falls preserving delicate water-soluble phases (King et al., 2022).

As this fresh meteorite fall's associated orbital information could arguably represent the UK's first asteroid sample return mission, work to study this special stone was divided into teams modeled on thematic Science teams of asteroid sample return missions such as JAXA's Hayabusa2 and NASA's OSIRIS-REx.

In this special issue of Meteoritics & Planetary Science, this consortium of researchers now report in-depth analysis of the Winchcombe meteorite. McMullan et al. (2023) report that the Winchcombe meteoroid had a relatively short residence time in Near-Earth space before

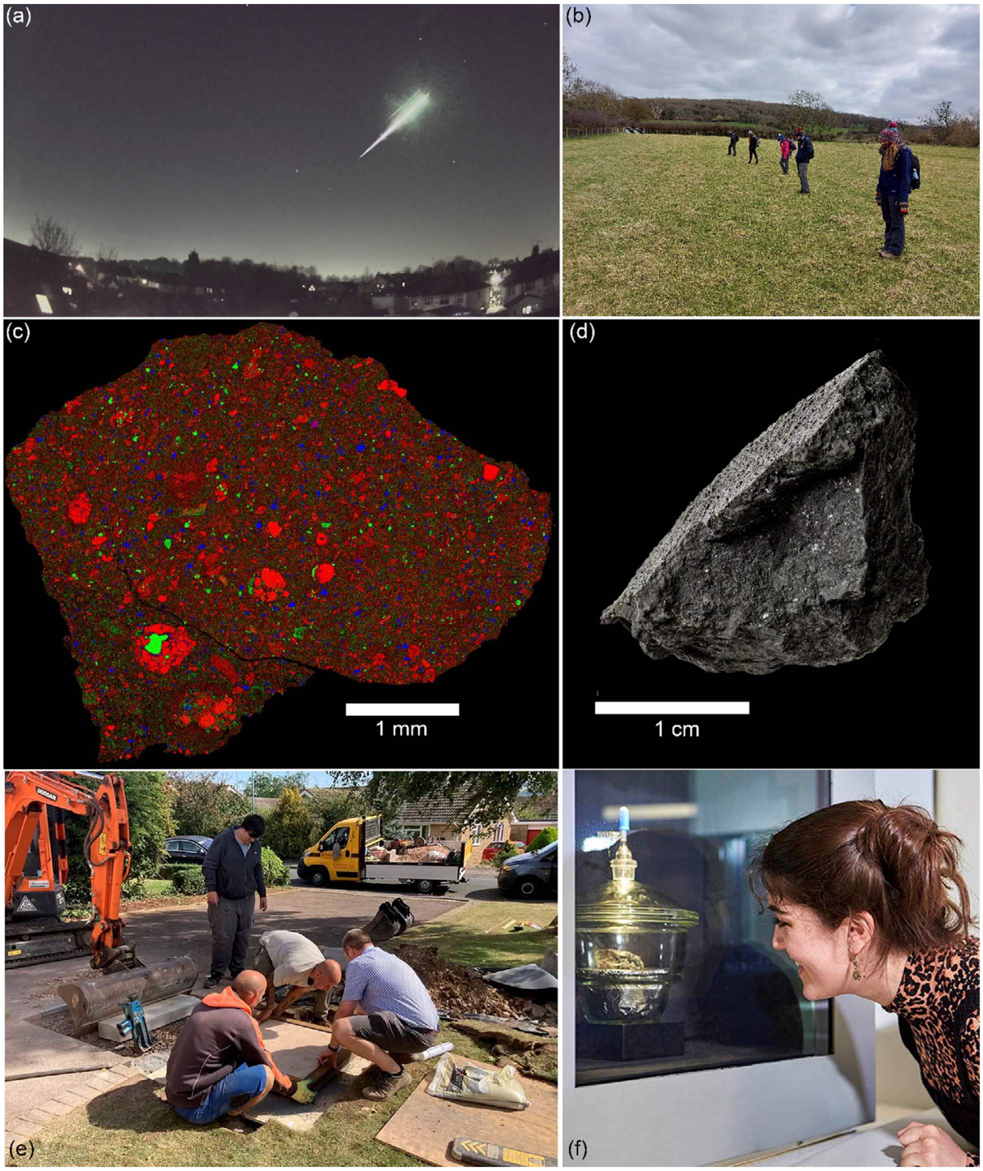

FIGURE 1. (a) Winchcombe fireball entry event captured on camera (Image: from a video by Ben Stanley, processed by Markus Kempf, the AllSky7 network). (b) Systematic line searching in farm fields to the north east of the village of Winchcombe on the 5th March 2021 (Image: Katherine Joy). (c) False-color qualitative element distribution image of thin section P30541 where red, Mg; green, Fe and blue, Ca (Image: data taken by electron dispersive spectrometer scanning electron microscope from Suttle et al., 2023). (d) Hand specimen of Winchcombe (sample BM.2022,M1-1), left face has a fusion crust, right side is interior broken surface (Image: courtesy of the Trustees of the Natural History Museum, London). (e) Extraction of a section of the driveway of the Wilcox family in Winchcombe to preserve the small impact crater made by the impact of the main meteorite mass (Image: Jonathan Amos BBC, 2021). (f) Hannah Wilcock, a member of the family whose house's drive was impacted by the falling meteorite, viewing an intact fragment of Winchcombe (sample BM.2022,M9-2) found in a field by the University of Glasgow search team. The sample is on display at the Natural History Museum, London (Image: courtesy of the Trustees of the Natural History Museum, London).

impact; it only narrowly survived atmospheric entry (Figure 1a) and, as such, it was the smallest observed carbonaceous body known to date to have dropped a meteorite. Genge et al. (2023) discuss the structure and composition of the meteorite's fusion crust formed during this entry event. They report the discovery of glass droplets transferred from another stone in the Winchcombe meteor shower, providing first evidence for intershower transfer of ablation materials. Russell et al. (2023) discuss the meteorite field search campaign (Figure 1b), and the sample curation approach at the Natural History Museum, London (Figure 1c). Jenkins et al. (2023) investigate the terrestrial alternation of the meteorite finding that surface sulfates, fusion crust calcite, and halite all post-date Winchcombe's entry into the Earth's atmosphere, indicating how rapidly meteorite falls can be terrestrially altered. Bates et al. (2023) report on the correlated bulk analyses on multiple subsamples of the Winchcombe meteorite, including the modal mineralogy, infrared spectral parameters, water content, elemental composition, iron distribution, and iron oxidation state. Curtis et al. (2023) measured the bidirectional reflectance distribution function of the Winchcombe meteorite across a range of viewing angles to provide a method of comparison with other meteorites, to produce Hapke parameter values used to provide a reference photometry dataset for current and future asteroid missions. The petrology of the sample is discussed in Suttle et al. (2023) and Daly et al. (2023) who conclude that Winchcombe meteorite is a complex millimeter-scale breccia containing fragments of primitive accretionary rock that were variably affected heterogeneously by aqueous alteration. The heterogeneity in aqueous alteration states could be caused by multiple disaggregation and re-accretion events on the CM parent body. The organic chemistry of the meteorite is discussed by Chan et al. (2023) and Sephton et al. (2023) who find that the soluble organic and macromolecular fractions indicate that Winchcombe is comparable to other CM chondrites and was derived from a lithology that has experienced brief episode(s) of aqueous alteration. Verchovsky et al. (2023) determined the evolved gas chemistry of Winchcombe showing that it has commonality with CM2 meteorites, although has a distinctive CO_2/CO ratio which could be linked to lower degree of terrestrial contamination. Greenwood et al.'s (2023) isotopic analysis shows the similarity between Winchcombe and other CM meteorites, and that while different lithologies within an individual CM2 meteorite are aqueously altered to different extents, each meteorite is characterized by a predominant alteration type. Bryson et al. (2023) discuss how the unique magnetic mineralogy of the Winchcombe meteorite enables it to unlock the clearest understanding to date of the magnetic field that threaded the protoplanetary disk in the outer solar system.

In addition to the rich scientific knowledge discussed in this MAPS special issue, we highlight the incredible public engagement opportunities that the Winchcombe meteorite and the people involved in its story have enabled. Thanks to the generosity of the landowners on whose property the meteorite was found, pieces of Winchcombe are now on display at the Natural History Museum, London (Figure 1f), and at the Winchcombe Museum, The Wilson Art Gallery and Museum in Cheltenham, Gloucestershire, and Amgueddfa-Cymru—Museum Wales in Cardiff. The meteorite was also put on display at the 2022 Meteoritical Society's annual conference in Glasgow, UK, at the Royal Society's 2022 Summer Science exhibition (MetSoc, 2023), at the UK's Bluedot Music and Science Festival in 2022, and the 2022 Cheltenham and British Science festivals. Furthermore, the Winchcombe meteorite featured on several UK high profile national TV shows including the "*The Sky at Night*" and "*The One Show*" made by the BBC.

The national public and international media engagement opportunities generated by displaying the meteorite and contextual content has been immense—for example, the Winchcombe museum estimates that in 2022–2023 the display attracted treble the amount of visitors than pre-COVID-19 numbers (BBC, 2023), and the 2022 Royal Society Exhibition was visited by 766 school aged students and 76 teachers (with 45% of schools coming from outside London), and 5007 members of the public (MetSoc, 2023). Shortly after the fall, researchers visited nearly 1500 students in the local Winchcombe area, and team members continue to share the story far and wide, delivering public seminars across the world and incorporating the recovery and results of the scientific analyses into undergraduate lectures for the next generation of planetary scientists. The success story of the Winchcombe meteorite is a testament to the power of collaboration without boarders bringing together international institutions and citizen scientists, and as such, the event was voted by UK scientists as one of the top 10 science stories of 2021 alongside COP 26 and the COVID-19 vaccine (Guardian, 2021). This cultural capital success evidences the importance of meteors and meteorites in capturing the public's interest, and as a "hook" scientists can use to develop impactful interactions that drives interest in STEM research and career pathways.

We thank the consortium thematic science leads Sara Russell, and Queenie Chan, Patricia Clay, Martin Suttle, Hadrian Devillepoix, Richard Greenwood, and James Bryson who helped manage the papers published in this special issue and those that will be forthcoming in future publications. We hope that you enjoy this special issue reading about the story of the lucky survivor, the Winchcombe meteorite.

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