

# UAV Imagery and 3D Modelling of Earthwork Heritage Sites in the Peak District National Park

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**1. ABSTRACT:** The preservation of earthwork heritage sites is of utmost importance as they are fragile and therefore vulnerable to external threats such as agriculture, urban encroachment, mining, tourism and climate change. However, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) made heritage a focal point in the Convention Concerning the Protection of the World Cultural and Natural Heritage adopted in 1972. Additionally, the United Nations Sustainable Development Goals 8 and 11 in 2015 outlined the need for promotion of sustainable tourism and preservation of heritage. Through utilising aerial imagery gathered using Unmanned Aerial Vehicles - drones - Structure from Motion (SfM) and GIS software, high resolution orthomosaic images, Digital Elevation Models (DEMs), and 3D models have been created of four earthwork monuments in the Peak District National Park. The level of resolution achieved from the collected aerial imagery ranges from 2-4 cm, higher than what is available as downloadable datasets from the Ordnance Survey. The intent of this presentation is to demonstrate the preliminary results of the modelling and inform on what more can be done with the data, such as visualisations of erosion and volumetric calculations, which can aid in heritage management, preservation and documentation.

## 2. METHODOLOGY

- Hundreds of images were captured with a UAV and imported into Agisoft MetaShape (Agisoft LLC, 2020).
- These were aligned using SfM (Structure from Motion) which finds matching points across images and aligns them. GPS readings are attached to each image. Using these features with ground control points means the images are aligned.
- Once aligned they go through a process of dense cloud formation, mesh and wireframe creation in order to provide the 3-dimensional shape (Figures 1 & 2).
- When completed, a Digital Elevation Model and orthomosaic (aerial image) is imported in GIS software.
- From the DEM, height data can be extracted from around the heritage monument to estimate what the hill- or country-side may have looked prior to construction of the monument. This is necessary for volume calculation.
- With volume calculation determined, and an estimation of the landscape prior to building, reconstructions using the contemporary height difference or archaeological estimations can be built in GIS with clear recording.

Figure 1: 3D model of Arbor Low

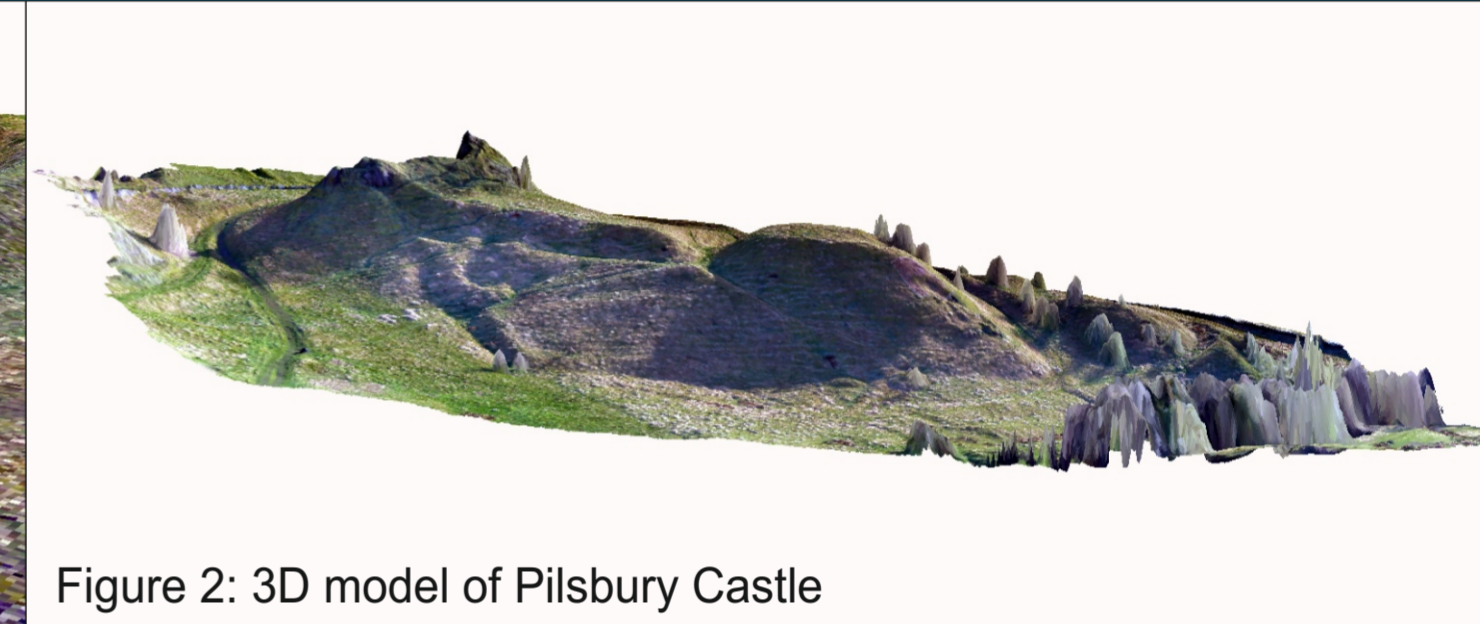


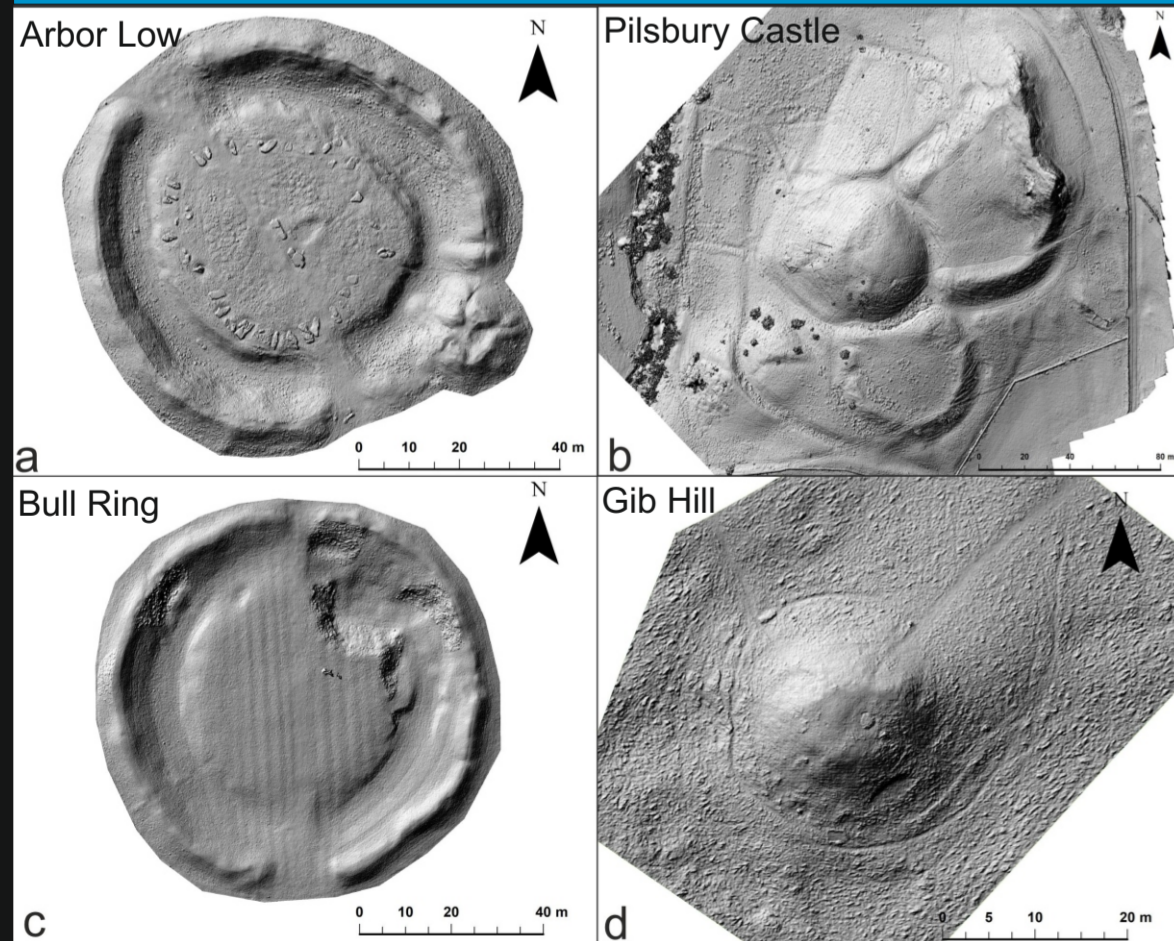
Figure 2: 3D model of Pilsbury Castle

## 3. PRELIMINARY RESULTS

- Four highly detailed and high resolution 3D models of Arbor Low (Figure 1), Bull Ring, Pilsbury Castle (Figure 2) and Gib Hill.
- Hillshades of all sites (Figures 3a-3d) that aid in visualisations of erosion damage, such as livestock and/or human made pathways.
- Slope images (Figures 4a-4d), similar to hillshades, have defined areas of damage, such as on Arbor Low (Figure 4a), and the severe quarrying at Bull Ring (Figure 4c).
- DEMs that show height (Figures 5a-5d) are necessary for volumetric calculation and potential reconstruction of these sites where possible.

## 4. INTENDED OUTCOMES

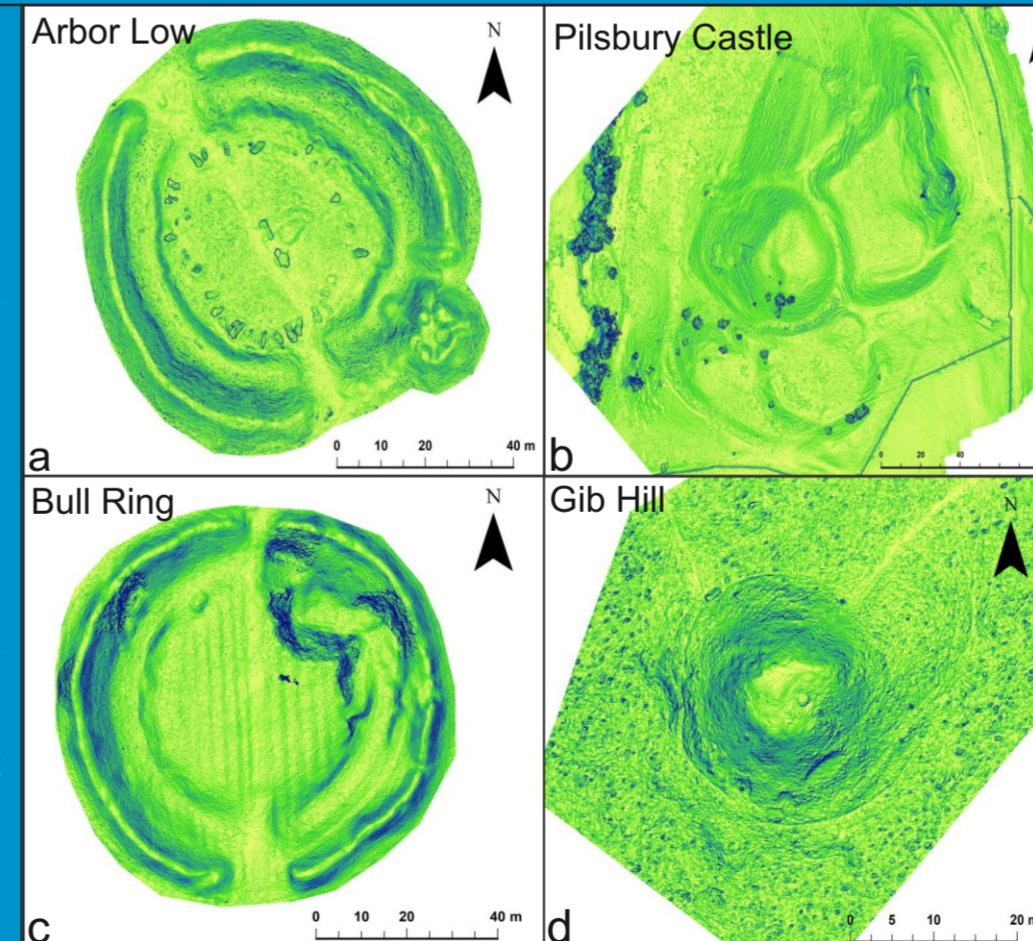
- The London Charter (2009) outlines rules regarding transparency and recording of heritage reconstruction; this investigation intends to rebuild heritage sites where doable with clear distinction that they are hypothetical modes.
- 3D models with provenance can be used in Virtual Reality (VR) such as Falconer *et al.*, (2020)'s work at Avebury.
- VR or online interactive heritage allows access to everyone with a computer, which is particularly important for disabled people who are commonly marginalised (Guttentag, 2010). It is also beneficial when there are restrictions in movement, such as the COVID-19 pandemic lockdown.
- By using GIS software for 3D modelling and not solely static 2D maps, this addresses Cerato and Pescarin (2013)'s need for 3D reconstructions due to inherent complexities.
- 3D models can be utilised as part of the UN Sustainable Development Goals 8 and 11 for promotion of sustainable tourism and protection of heritage (United Nations, 2015; Xiao *et al.*, 2018).
- The intended outcomes of this research is to show that UAVs can be an effective way to monitor earthwork heritage sites in moorland, and the results can be used for research and for public education.



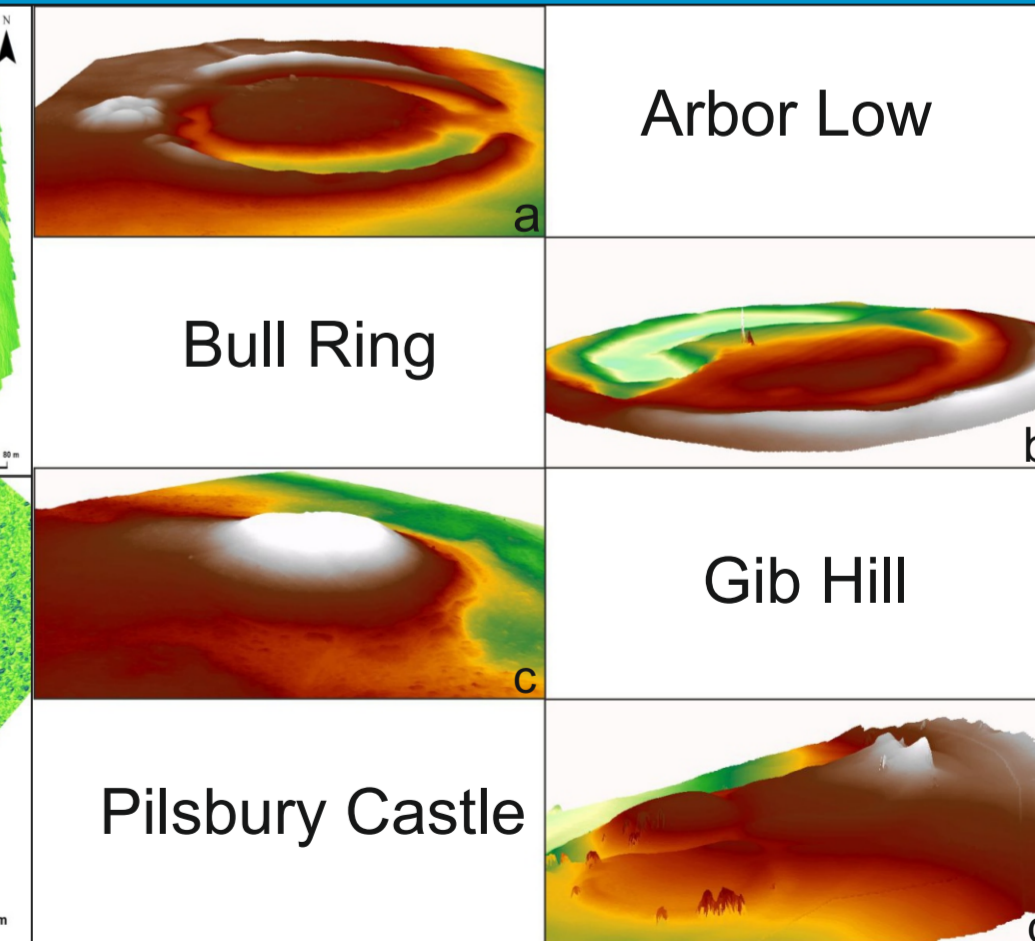
Figures 3a-d: Hillshades of the four sites. These can be used to identify areas of damage.

## 5. ACKNOWLEDGEMENTS

The investigators would like to thank Historic England, Peak District National Park Authority, the Dove Holes Community Association and landowners for giving permission to fly and capture these sites.



Figures 4a-4d: Slope images that display the degree of slope change, indicating areas that may be damaged.



Figures 5a-5d: These Digital Elevation models will be integral for the next stage of determining the volumes of the current sites, and compare with possible reconstructions.

## 6. REFERENCES

Agisoft LLC, (2020), ONLINE. <https://www.agisoft.com/about/>, accessed 4th November 2020; Cerato, I., and Pescarin, S., (2013), 'Reconstructing past landscapes for virtual museums', *In: Good Practice in Archaeological Diagnostics*, p. 285-296, Springer, Cham; Falconer, L., Burden, D., Cleal, R., Hoyte, R., Phelps, P., Slawson, N., Snashall, N., and Welham, K., (2020), 'Virtual Avebury: Exploring sense of place in a virtual archaeology simulation', *Virtual Archaeology Review*, 11(23), p. 50-62; Guttentag, D. A., (2010), 'Virtual reality: applications and implications for tourism', *Tourism Management*, 31(5), p. 637-651; London Charter, (2009), ONLINE. <http://www.londoncharter.org/introduction.html>, accessed 4th November 2020; United Nations, (2015), 'Transforming our world: the 2030 Agenda for Sustainable Development Summary', ONLINE. <https://sustainabledevelopment.un.org/post2015/transformingourworld>, accessed 4th November 2020; Xiao, W., Mills, J., Guidi, G., Rodriguez-Gonzalez, P., Gonizzi Barsanti, S., and Gonzalez-Agullera, D., (2018), 'Geoinformatics for the conservation and promotion of cultural heritage in support of the UN Sustainable Development Goals', *ISPRS Journal of Photogrammetry and Remote Sensing*, 142, p. 389-406