Using photogrammetry to interpret human action on Neolithic monument boulders in Ireland's Cavan Burren

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ABSTRACT

Digital technology has been increasingly employed in the documentation and analysis of archaeology in the last ten years. We utilized user-friendly digital photogrammetry and animation to assist in the analysis of archaeological evidence in Ireland. Our tools were commercially available software, a consumer-grade hand-held or tripod-supported digital camera, and a personal computer. The method was developed for and has been subsequently used by local archaeological surveyors in an extensive documentation of prehistoric settlement features within the Marble Arch Caves Global Geopark in Ireland. The boulder monuments are unusual in that they are made from glacial erratics whose surfaces display traditional North Atlantic rock art and a new sculpting art form. Pieces making up two boulder monuments were digitally manipulated via animation into what is believed to be their original source stone configurations. Their matching surfaces were studied in detail. The process was employed to demonstrate, non-invasively, how the monuments might have resulted from some actions other than weathering. The analysis supports the hypothesis that humans worked the monuments, which, in turn, supports protection of the monuments for further study.

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1. Introduction

Heritage sites rich with 3-dimensional, human-worked objects and rock-art surfaces continue to be recorded by scholars through the use of automated digital-capture programs. Multi-image photogrammetry calculates geometric information from large datasets, compares large sets of images simultaneously, and identifies matching features in an accurate, cost-effective, user-friendly manner. Researchers across a variety of archaeology sub-disciplines have increasingly recognized the advantages of combining multi-image photogrammetry, also known as Structure from Motion (SfM) software, with other forms of software to better analyze sites, features, structures, and objects (De Reu et al., 2013).

As an example of a large-scale documentation project, Guidi et al. (2009) integrated multiple tools in a 3D modeling of the Roman Forum in Pompeii by using digital data constituted from aerial imagery, augmented with range data (laser scanning) and terrestrial images (photogrammetry). They established core specifications for data acquisition and modeling, with an independently considered protocol for texture resolution and geometric resolution appropriate for specific artifacts. At a very fine scale, ambient occlusion (AO), a technique employed by video game animators in the entertainment industry, has been used to enhance surface variations to aid in the interpretation of controversial inscriptions on the Tristan stone (Spring and Peters, 2014).

Animation software can also be used. It was provided automatically as fly-around viewing of digital models in early generations of *123D Catch* software, initially released as *PhotoFly* (Autodesk Laboratories, 2010). However, animation programs can be used more deliberately. For example, McCarthy and Benjamin imported the textured mesh created by Agisoft's (2016) *Photoscan* software into Autodesk's 3D Studio Max (1999) modeling package and applied depth of field and underwater fog visual effects to create realistic flythrough videos that closely matched the experience of diving in the underwater site of a shipwreck. In addition, they used animation to confirm the match of the fragile silt-filled cannon barrels at the underwater site with 17th and 18th century drawings of a particular make of cannon. They digitally fit the shape of the appropriate cannonball into the digital mesh model of the cannon barrel artifact (McCarthy and Benjamin, 2014).

Animation software in concert with photogrammetry has significant potential to further non-invasive archaeological research. The current paper presents a non-invasive method for inspecting curious repetitive surface formations on monument stones located in the Cavan Burren, an area within the Marble Arch Caves UNESCO Global Geopark, the world's first international Geopark (Parkes et al., 2013). Established in 2000, the European Geopark Network (EGN) is a fast growing aspect of Earth Science conservation aiming to protect geo-diversity, promote geological heritage to the public, and support sustainable economic development through Earth Science based tourism (Gunn, 2009). Open to the public,

no portion of this Geopark is currently preserved or protected with any special cultural or heritage designation, which is an issue of concern.

The Cavan Burren is an upland karst landscape along the border of Northern Ireland's County Fermanagh but contained within the Republic of Ireland's County Cavan (Fig. 1). Its features include: a variety of stone field walls, both rectilinear (circa 18C) and concentric/radial (medieval or ancient); two classic hilltop wedge tombs, one of which is mostly collapsed and one which remains in cairn (Cummings et al., 2015); a portal tomb retrofitted by 19th century farmers into a calf house; and a dense scattering of significant sandstone boulders (Burns and Nolan, 2007b). Some boulders are grouped in circles. Others are perched on limestone pedestals; some of which have been reduced leaving interesting spaces beneath the boulders. Yet other boulders have clear cup-and-ring rock art motifs, or apparently anthropogenic sculpting, which Burns and Nolan (personal communication, 2012) believe to be a form of early Bronze Age or late Neolithic art.

These boulders, unlike the local limestone material, match the composition of the distant Cuilcagh Mountains and likely were transported during the last glaciation, 13,000 years ago (Lemon, 2010). Due to the high solubility of the limestone, many sandstone boulders are perched on what appear to be limestone pedestals; i.e., the depth of approximately a foot of the surrounding unprotected karst ground-plane has been worn away, leaving only the limestone protected by the overhang of the boulder itself (Lemon, 2010). Some of these pedestals appear to be modified, perhaps by human action, as do some of the boulders (Gunn, 2009). Other arrangements of apparently modified boulders include deliberate splitting and rearrangement of slabs, creation of chambers, insertion of single or multiple chocks, and a variety of other stone arrangements including the addition of kerb stones (Cummings et al., 2015; Kytmannow et al., 2008). Of the 336 boulder monuments known by 2014, 90 are perched on pedestals and 200 are decorated with rock art and/or sculpting (Burns and Nolan, 2007a). Over 100 of
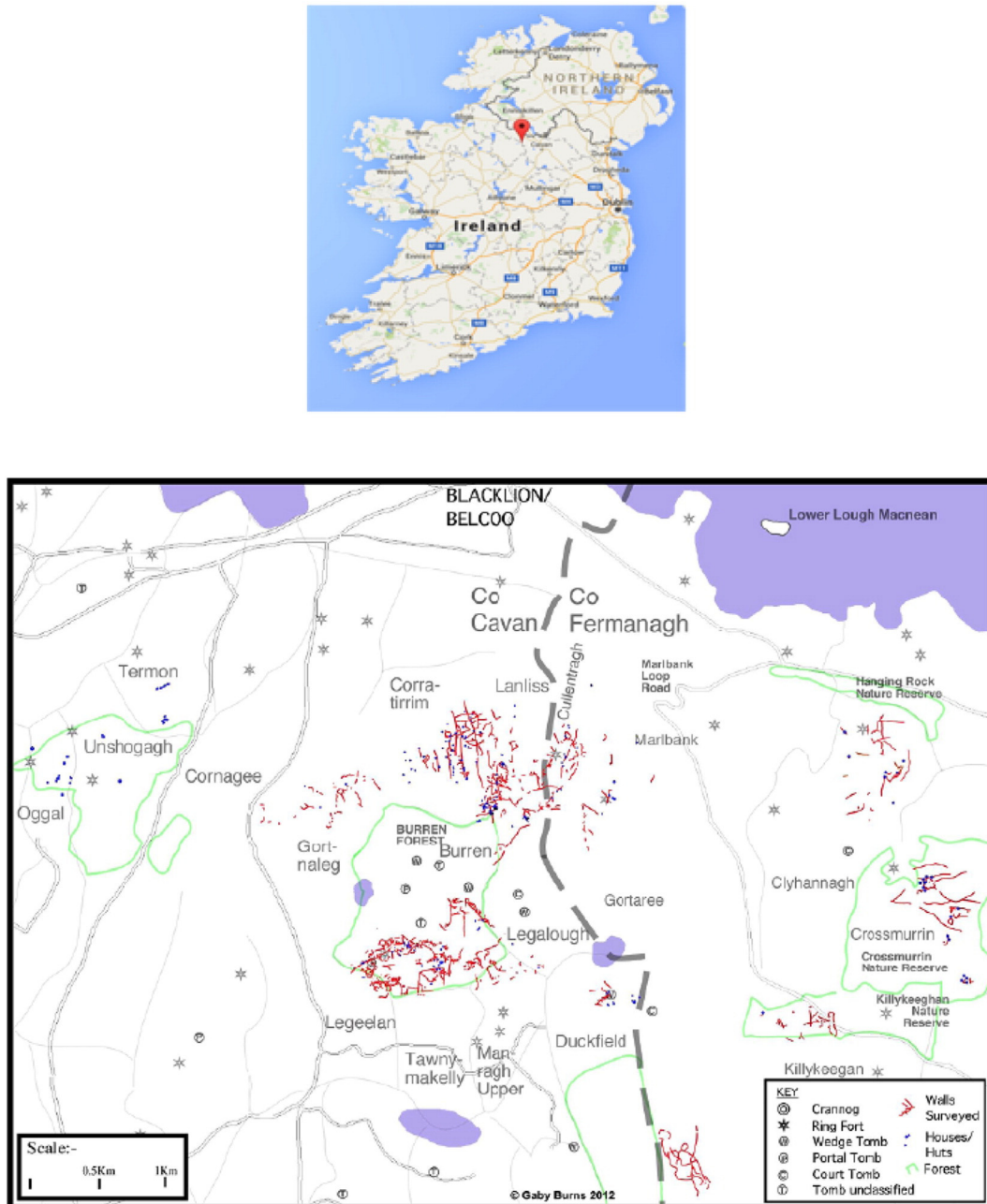

Fig. 1. Location of Ireland's Cavan Burren.