Quaternary International xxx (2015) 1–8

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Shape as an outcome of formation history: Terrestrial Laser Scanning of shell mounds from far north Queensland, Australia

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A R T I C L E I N F O

Article history:
Available online xxx

Keywords:
Terrestrial Laser Scanning
Shell mounds
Formation history
Coastal archaeology
Australia

A B S T R A C T

Terrestrial Laser Scanning (TLS) is a laser-based surveying system that enables rapid measurement of x,y,z coordinate points, creating an accurate representation of objects in three-dimensional space. We apply this technique to the survey and analysis of mounded shell matrix deposits (SMDs) near Weipa in far north Queensland, Australia. Eleven parameters were used to characterise the size and shape of 51 shell mounds located in one geographical area. The results demonstrate substantial variation in mound size and shape, and suggest patterning in mound form related to age as well as position on the landscape. Radiocarbon chronologies developed for a sample of the 51 mounds demonstrate that the mounds do not conform to a model of linear formation of a shell deposit, suggesting mound histories are variable in both the nature of shell deposition as well as post-depositional processes. These results have important implications for interpreting the processes responsible for shell mound formation.

1. Introduction

Terrestrial Laser Scanning (TLS) is a laser-based surveying system that enables rapid measurement of x,y,z coordinate points, creating an accurate representation of objects in three-dimensional space. It is non-contact, non-invasive and non-destructive, and the resultant data sets can be used to produce detailed and precise three-dimensional spatial images and models that can be analysed, measured and manipulated in a computer environment (Collins and Doering, 2009: 28). Currently, the majority of archaeological applications of TLS focus on the conservation and management of cultural heritage (e.g., Yastikli, 2007; Lerma et al., 2010; Haddad, 2011), particularly through a combination of TLS with phototexturing to create realistic three-dimensional representations (e.g., Andrés et al., 2012; Rodríguez-Gonzálvez et al., 2012; Domingo et al., 2013). However, it is also possible to use the technique to create accurate and precise models that permit quantitative investigation of structures that are difficult with more traditional techniques that record spatial information. Here, we report on the analysis of the shape of shell matrix deposits (SMDs) that are a prominent feature of the landscape of Albatross Bay, Cape York Peninsula, Australia. There are estimated to be upwards of 500 SMDs in this region (Bailey, 1999; Shiner et al., 2013). They are found in close proximity to the four rivers (Pine, Mission, Embley and Hey) that drain into Albatross Bay (Wright, 1964; Bailey et al., 1994). The SMDs are predominantly composed of a single shellfish species, the bivalve *Anadara granosa* (Morrison, 2003). In addition, the SMDs are very significant cultural sites for Traditional Owners and whilst invasive research methods such as excavation have been permitted, the three-dimensional scanning of mounds prior to excavation creates a permanent digital record of the pre-excavation condition of mound that can then inform the post-excavation reconstruction of the mounds. This record can also be compared to similar records taken at future times allowing changes in mound size and form to be quantified. The ongoing preservation of the mounds and having a record for future generations is a key concern of the Aboriginal custodians.

The SMDs of Albatross Bay are an ideal setting to investigate how different processes have influenced the form of the deposits, since visually the mounds appear to vary in their shape and size as well as geomorphic contexts. The SMDs have previously been reported to show a range of forms (Bailey, 1999; Morrison, 2003), from small scatters to instances of *umådeligmødding* (mega-middens) or shell mounds of up to 14 m in height (Bailey et al., 1994: 69) and up to 100 m long (Morrison, 2010). The SMDs are

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http://dx.doi.org/10.1016/j.quaint.2015.06.066
1040-6182/

located on a variety of landforms, such as the bauxite plateau which is the dominant landform in the region, sandy and gravelly shore-parallel ridges, and estuarine mud flats. A small number have recently been found within the mangroves that fringe the estuaries (Shiner et al., 2013; Fanning et al., submitted for publication). The current chronologies show the SMDs date from the mid-Holocene to recent times (Fanning et al., submitted for publication; Morrison, 2013a, 2014).

This study focusses on 51 SMDs from Wathayn (Fig. 1), an area approximately 25 km south east of Weipa. As all of the deposits included in the analysis have some vertical relief, the term "shell mound" will be used hereafter to refer to the SMDs (after Morrison, 2013b: 81).

2. Shell mound morphology and TLS

Several techniques have previously been used to measure and quantify the morphology of shell mounds. In an early study in 1972, Bailey (1975, 1994) measured the height, base area and slope angles of 306 mounds, including a sample of the Wathayn sites, with a combination of tape measure, clinometer, eye-estimation, and pacing, and calculated mound volumes using a variety of geometrical formulae based on standard shapes, and cross-sectional areas for more irregular shaped mounds. Theodolites have been used in the majority of more recent investigations to record a regular grid of three-dimensional co-ordinates (x,y,z), from which contours have been derived (e.g., Hiscock and Hughes, 2001; Russo, 2004; Sanger and Thomas, 2010). Such records may provide a good approximation of shape for a large number of mounds in a variety of field settings but are often limited in their accuracy by the low density of measurements taken on any one mound. The difficulty is that complex shapes may require large numbers of points for accurate modelling, a problem that is also discussed in the literature documenting the ongoing attempts to create accurate three-dimensional representations of caves where important deposits and ancient rock art are found (e.g., González-Aguilera et al., 2009; Lerma et al., 2010; Núñez et al., 2013).

LiDAR (Light Detection and Ranging) provides a solution since it allows the rapid but accurate measurement of dense quantities of spatial information across large and morphologically complex areas. The spatial position of each data point is calculated using the known angle of the emitted laser, the speed of light, and the time of flight of the laser. Ground based LiDAR (Terrestrial Laser Scanning) can be used over distances from less than 1 m to over 100 m. Scans produce a large number of x,y,z points in a common coordinate system that form a point cloud. The speed and accuracy of TLS provides the capability to generate precise models of multiple mounds which can then be quantified and compared. However, TLS is also an indiscriminate recording technique, in that it records the surface of whatever the laser strikes. The technique does not differentiate between the object of interest and the surrounding landscape. Objects of interest must therefore be separated from the point cloud during the post-processing phase.

3. Data collection, processing and model construction

In the research reported here, a Leica Scanstation 2 was employed over two fieldwork seasons in 2010 and 2011, upgrading to a Leica C10 for the 2012 season. The two machines have a maximum scan rate of 50,000 points per second with a positional accuracy of 6 mm and 4 mm, respectively, in depth. For both machines, a laptop computer controlled the laser scanner, which facilitated the process of determining the area to be scanned, and allowed immediate review of completed scans to assess black-spots in the point cloud. Leica High Definition Survey (HDS) targets were employed as georeferencing tools. The targets were mounted on tripods and provided common points in multiple scans that could be used for automatic georeferencing. A field record of scanner and target attributes (height, GPS position) as well as scanner position relative to the mounds mitigated any difficulty in identifying

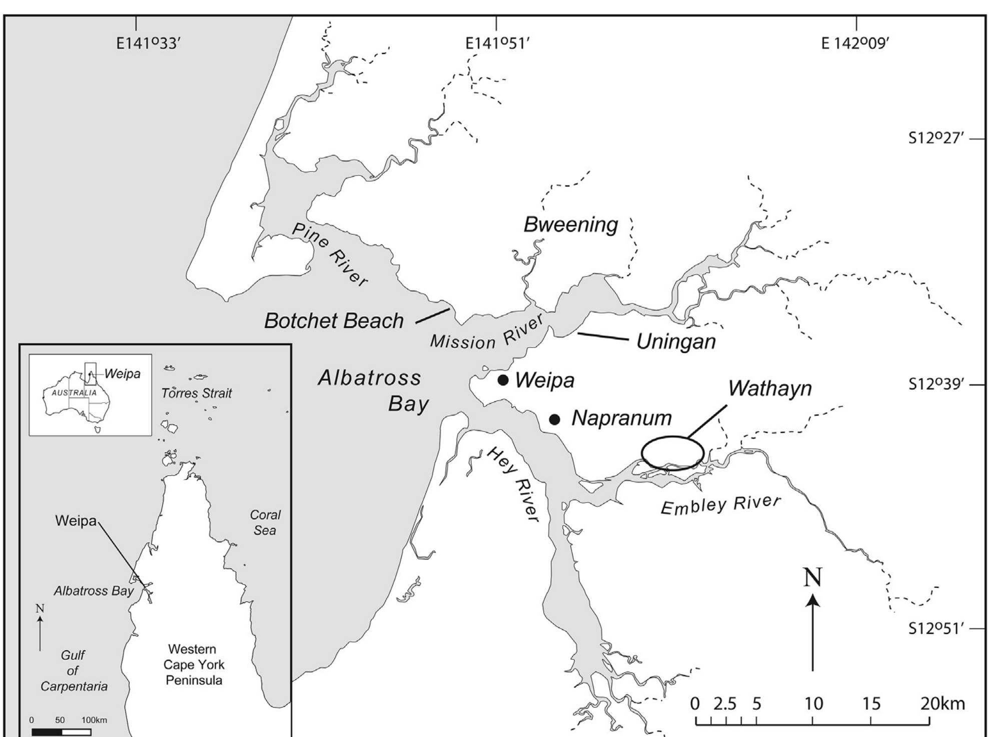

Fig. 1. Location of the Wathayn study area in far northwestern Cape York Peninsula, Australia.

Please cite this article in press as: Larsen, B.P., et al., Shape as an outcome of formation history: Terrestrial Laser Scanning of shell mounds from far north Queensland, Australia, Quaternary International (2015), http://dx.doi.org/10.1016/j.quaint.2015.06.066