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The survey and analysis of brochs

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The survey and analysis of brochs

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ABSTRACT

Developments in surveying technology over the past decade have facilitated new approaches to the survey and presentation of complex upstanding archaeological sites. Recent surveys carried out on behalf of Forestry Commission Scotland, allied to ongoing research into the architecture and engineering of brochs – or complex Atlantic roundhouses – across Scotland, have prompted a reassessment of approaches to the recording and interpretation of brochs as structures and a reconsideration of the information required to record their character. This paper highlights the importance of archaeological measured survey and explores the influence of zeitgeistic preconceptions, not only on the survey itself but on its interpretation. Pre-survey analysis, selection of evidence to be surveyed and post-survey analyses are intimately interlinked. While modern survey techniques address some of these issues, improvements in recording must be matched by improved interpretational models to maximise their benefits to broch studies.

INTRODUCTION

> In studying these interesting structures the value of complete and accurate plans cannot be too strongly emphasised
>
> (John Wilson Paterson 1922: 183).

More controversy surrounds the significance of the structural schema of Atlantic roundhouses – the full range of massive-walled roundhouses encompassing brochs and related buildings – than any other class of prehistoric monument in Britain. The details of the architecture (not essential for structural integrity) and engineering (structural elements) of these buildings have significant implications for the modelling of the communities that built them, and disagreement over the interpretation of the surviving remains of brochs has fuelled the ongoing debate about their significance in later prehistoric society. The study of brochs, now often termed 'complex Atlantic roundhouses', has long been concerned with architectural typology. Many authors have sought to describe and define brochs, illustrating their arguments with simple plans, often reduced and replicated. Few detailed archaeological measured surveys are commissioned or undertaken, even of those structures in the care of the state. Clearly, modern archaeological measured survey is of paramount importance in enhancing the historic environment record by creating a detailed structural record and by informing conservation management. It also enables effective and considered studies and can provide a scientific platform for electronic heritage interpretation, both on and off-site. We argue here that analyses of the engineering and architecture of brochs, using the most appropriate tools, is essential to understanding the motives and intentions of the builders and thereby to approaching an understanding of the role of brochs in Iron Age society. Indeed, we propose that existing social interpretations of brochs are too often based on weak analyses of the structures themselves.

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HISTORY OF BROCH SURVEY AND STRUCTURAL ANALYSIS

The historiography of antiquarian interest in brochs and related monuments has been collated and discussed by several previous authors, most recently by MacKie in his authoritative corpus of brochs and related Atlantic roundhouses (2007: 31–44). It is therefore not necessary to rehearse again the history of archaeological investigation of drystone roundhouses. This paper focuses on the production of metrically accurate plans and elevations that have accompanied previous investigations and the parameters of their interpretation.

The first accurate records of the structural details of drystone towers were produced by Henry Dryden and F W L Thomas. Dryden and Thomas were both accomplished surveyors, and the detail reproduced in their depictions of brochs is remarkable. Their acute observation, detailed inspections and careful measurements informed the earliest understanding of the function of broch structures. They established the groundwork for the appreciation of broch towers as complex and accomplished structural achievements (MacKie 2007: 32). In particular, the publication of the surveys of Mousa, Dun Carloway and Clickhimin generated the evocative symbol of the broch tower. Mousa, in particular, became a stereotype unquestioned for decades and although rejected as a such by Fojut, its influence remains potent. In the first half of the 20th century, published plans and sections generally resulted from excavations, such as those of Dun Telve and Dun Troddan in Glenelg by A O Curle (1916 and 1921 respectively), or of Dun Beag on Skye by Graham Callander (1921). Although such early surveys were primarily intended to illustrate rather than record (and often prioritised interpretation over metrical accuracy), those undertaken by the architects of the Office of Works (in support of excavation or prior to consolidation or repair) are examples of good practice. The comprehensive and detailed measured survey of the broch of Mousa, for example, was published by John Wilson Paterson, the 'Architect in Charge', after repair works in 1919 (Wilson Paterson 1922); and his plans and elevations of Dun Telve were published by Curle (1916).

Controversy over the interpretation of the significance of their architecture began in earnest with the publication of Sir Lindsay Scott's assessment of the brochs of the Outer Hebrides, which took a pioneering approach to their landscape-centred study (Scott 1947). Scott postulated that the surviving heights of many monuments were often not consistent with the requirements of tower-like buildings, preferring instead to see the majority as relatively low structures, in three main height groups, a view which contributed to his conclusion that brochs were to be thought of as farmsteads of a socially differentiated population, rather than exclusively as residences of an elite (Scott 1947). Scott's reading of the physical evidence was directly contradicted by that of Angus Graham, who identified the presence of architectural traits such as the non-utilitarian thickness of the wall, intra-mural galleries and weight-relieving voids as structural accommodations to the loads created by a tall structure, and therefore making little sense in buildings of single storey or modest height (Graham 1947: 91).

Graham's analyses of the significance of architectural traits were made possible by the collation of larger numbers of surveys than had ever been produced before, due to the systematic surveys of the RCAHMS and in particular of A O Curle, who prepared large numbers of ground plans of broch sites from across the Highlands. Curle assessed some of the recurrent themes of broch studies, considering structural traits, chronology and origin, concluding that '… the typical broch is a circular structure, a species of tower, built entirely of drystone masonry …' (Curle 1927: 290). For the first time, large numbers of simple plans were available for comparison, allowing the kind of typological studies with which archaeologists were then most comfortable and forming the basis for the ensuing discussion of Atlantic roundhouses in culture-historical terms (eg Childe 1945).

Graham was also interested in adding to the overall corpus and undertook some detailed surveys of his own. He recorded the broch of

Caisteal Grugaig during the summer of 1949, the written description augmented by a measured survey and photographic record (Graham 1949: 12–24). The innovative 'elevation of the interior developed on the flat' used by Graham, a keen proponent of raising standards in archaeological recording and publication, at Caisteal Grugaig (1949: 15) and at Dun Telve (1947: 83) remains a very useful illustrative style, highlighting the entrance passage and scarcement (Dunbar 1992: 37).

Papers in the 1980s progressed the study of brochs through analyses of the dimensions and possible structural configurations, with analysis of the surveyed dataset forming the basis for a discussion of what constituted a 'typical broch', with the memorable conclusion that while Mousa is a broch, not all brochs were like Mousa (Fojut 1982: 227); and of concepts such as access analysis (Foster 1989). It is ironic indeed that Mousa, the exemplar broch, is the least typical and least representative of all of the monuments variously defined or described as brochs.

Martlew's typological study attempted to identify the defining characteristics of geographical zones through statistical analysis of the existing dataset, albeit with the recognition that new and more accurate data could readily alter the emerging pattern (Martlew 1982: 228). Fojut's PhD study tested and confirmed Scott's Hebridean views on the brochs as functioning parts of an agricultural landscape (Fojut 1982), by showing their correlation with soil types in Shetland, and, somewhat in corollary, their lack of correlation with the more defensible sites available in their immediate environs.

Analysis of ground plans was also the foundation of the review of brochs that led to the current model for the classification of these structures. Armit argued that the division of roundhouses into 'true' brochs and variant duns introduced artificial divisions that masked an overriding similarity in form. In summary, the collation of all related brochs, duns and galleried roundhouses into a wider class of 'Atlantic roundhouses', comprising complex and simple forms allowed Armit to draw attention to the fact that a general similarity in form was their most significant shared characteristic (Armit 1992). The identification of the developed-tower subset of the 'complex Atlantic roundhouse' category acquired a central importance in the debate about the social significance of the Atlantic roundhouses, since the view of the broch tower as the residence of powerful elites, occupied by a small minority of the population versus the broch as the standard Iron Age house in Atlantic Scotland again resurfaced as a point of contention (see Sharples & Parker Pearson 1997; Armit 1997a; 1997b).

Terminology and classification, then, have consistently been at the heart of the debate over the interpretation of the social roles of brochs in Iron Age society. The quality of the surveyed record, however, is variable in consequence of a range of factors. The distinction between sites likely to have been towers and those more limited in stature is one which is not always easy to make, based on existing published information. Imbalances of modern fieldwork and excavation have polarised attitudes to the limited evidence and have made considered typological overviews difficult (Ritchie 2005: 1). The generic reproduction of archaeological plans at a simple scale for ease of publication has, conversely, had a conservative effect on the study of complex Atlantic roundhouses and perhaps hidden structural variations and traits (for plan-based discussions, see Harding 1997 or Gilmour 2005, amongst many more).

These actual or postulated differences in structural detail and in scale are significant because of their implications for the social context of broch building. The greatest cost in broch building was quite certainly the quarrying and transport to site of the stone used in the construction. The use of ground plans alone can be misleading: the volume of a structure increases as the cube of the linear increase in the plan modulus. Thus, in the simplest case, doubling the length of a wall increases its square dimensions (area) fourfold and its cubic parameter (volume) eightfold. The height of the broch is a useful gauge of the quarrying and other costs of its construction and this in turn is a gauge of its social significance to its builders. In addition to construction costs, the opportunity costs (the 'cost' in terms of lost benefit of not doing something else with the committed resources) amplify the social significance of the building project. In every respect other than the typology of ground plans, then, the available broch dataset is not suitable for the exploration of the questions we now seek to ask of it.

Euan MacKie (1965: 103) has set out the criteria that he believes are indicative of the existence of a broch tower, even in substantially dilapidated remains:

1. Existence above the ground floor of a drystone built tower with characteristic complex wall structure; or proxy evidence for same:
   (a) Surviving evidence for at least one upper gallery
   (b) The existence of a weight relieving void or gap over the innermost door lintels (ie a 'stacked void').
2. Massive ground floor wall, sufficiently thick to reduce the diameter of the enclosed garth to 40% to 65% of the external diameter (ibid).
3. Circularity of ground plan.

Following the excavations at Clachtoll, Assynt, and observations elsewhere, one of us (JB) has added a further criterion, viz:

4. The use of massive or complex, composite-beam-type lintels over the outer end of the entrance passage.[1]

Bias in evidence selection for the survey and the interpretation of brochs

It is noteworthy that although Dryden (1890: plate XVIII) illustrated a composite-beam arrangement of lintels at Clickhimin over a century ago, its significance has not been noted to date. By setting the outermost lintels on their diagonals, the builders ensured that the maximum thickness of stone was used to support the outer wallface. At Clachtoll and at Caisteal Grugaig (the latter also surveyed by Dryden), by simply turning the outermost group of entrance-passage lintels so that their maximum cross sectional dimension is upright, their ability to resist the loading of a massive external wall is maximised. Other solutions, such as the use of corbelling between these outer lintels (Clachtoll) and over the entrance, or by insertion of a triangular lintel slab, achieve the same end. These accommodations have all been recorded more than a century ago, but the recognition that they create a substructure capable of supporting massive loadings and are thus indicative of the existence of those massive loadings in the form of a broch tower has, apparently, not been explicitly noted or discussed, albeit that MacKie is clearly conscious of its significance.

A scanning laser records millions of three-dimensional points within boundaries set by its field programmer. The surveyor does not select the individual points in any way and certainly does not select the objects, ie individual stones or stone wallfaces, etc. Manual surveys record an interpretation already made and are, collectively, a method for illustrating a pre-conception, usually one based on the current zeitgeist in broch studies. Recording monuments by laser scanning avoids the influence of zeitgeist in survey. Evidence gathered in support of interpretation, being a subset of all the available observations, is inevitably selective and subject to biases that commonly arises from the contemporary zeitgeist. Previous critiques have asserted that non-contact methods like laser scanning remove the surveyor from the process of interpretation, and there may be some truth in this. However, unlike the manual survey, a laser scan remains capable of interrogation and reinterpretation by others while the manual survey cannot allow interrogation of observations it did not record. Interpretation and survey are separate operations and it is noteworthy, for example, that Dryden, who produced the best of the antiquarian broch surveys, made no significant contribution to the subject. Laser scanning does not include a bias-free interpretation, it merely provides a record from which alternative interpretations can routinely be derived. Traditional survey is less amenable to subsequent reinterpretation.

Brochs and duns are upstanding drystone masonry monuments. Recording surviving architectural features – and the extent of their surviving heights – should be the primary concern of survey. Traditional survey methodologies were designed to fit a limited technological capacity with the strategic aim of acquiring large quantities of information within limited fieldwork exercises: most broch surveys carried out in the 20th century were undertaken using manual techniques, typically deploying plane table and alidade or offset tapes. For the most part, such surveys, in effect, discard the vertical dimension and focus on producing ground-level plans. In this task they have proved fit for purpose: providing the traditional ground plans. The intellectual costs involved, however, are high. Simple surveys service and reinforce the zeitgeistic view and neither in their compilation in the field nor in their subsequent analysis have they challenged the status quo.

ARCHAEOLOGICAL MEASURED SURVEY AND CULTURAL RESOURCE MANAGEMENT

The development of archaeological measured survey in Scotland has been discussed at length by others and has largely focused on the activity of RCAHMS (see Dunbar 1992; Halliday & Stevenson 1991). For prehistoric monuments, the methodological development comprised site-based cataloguing in Inventories that progressively included landscape-scale mapping and recording. Sites were surveyed on plan and, sometimes, included within their immediate landscape settings. Following the development of the traditional RCAHMS Inventory into its more discursive descendants (eg RCAHMS 2007), RCAHMS turned to thematic archaeological study with the magisterial 'Great Crowns of Stone' (Welfare 2011), analysing the recumbent stone circles of Scotland and presenting their measured survey in plan and by elevation.

Survey and cultural resource management

The importance of archaeological measured survey within cultural resource management cannot be overestimated. Survey provides a record that to greater or lesser degree approximates to a level of completeness that can inform conservation management and allow detailed condition monitoring. Illustrations deriving from measured survey raise the public profile of significant sites and greatly enhance the wider historic environment record, and detailed surveys facilitate effective structural analysis and condition monitoring. The images from archaeological measured survey are readily appreciable by non-specialists and can effectively demonstrate and confirm the importance of a monument to land managers and visitors.

The concept of communicating archaeology to the public is now an important and accepted element of most archaeological projects. However, within the confines of cultural resource management (where the protection of the historic environment resource is seen as a duty undertaken today on behalf of future generations), the archaeological process is often wholly undertaken outwith public view (see Barber et al 2008). From original specification to execution, analysis, reporting and archiving, the archaeological process can be undertaken without much thought directed to publication, considering the 'historic record' as suitable for archive only. Illustration – one of the most powerful communications tools at our disposal – can be perfunctory at best.

Beyond development control, upstanding archaeological sites (predominantly in the rural context) need to be protected from damage by erosion, stock poaching, tree and scrub growth, casual neglect and deliberate vandalism. While natural processes such as structural dilapidation over time cannot be avoided without recourse to proactive conservation, those pressures on archaeological sites that are caused by human activity or land use can, in some instances, be avoided or minimised. While protection often simply involves the avoidance of damage or the removal of scrub vegetation, positive action can also include the creation of a comprehensive record. However, within the remit of cultural resource management, archaeological measured survey has long been seen as an element of 'preservation by record' (Macinnes 1991: 198). It is seen as the necessary precursor to loss or intervention, as simply the means to an end. It is rarely undertaken (or even encouraged) as a positive activity, independent of other requirements (the recent RCAHMS Scotland's

Rural Past project being an admirable exception – see RCAHMS 2011).

Conservation of brochs

The care and conservation of unconsolidated drystone complex Atlantic roundhouses has rarely been considered outside of site-specific conservation plans (see for current example, Clachtoll broch; Barber 2011). Some, perhaps many of the early conservation interventions would not now be acceptable (see Burra Charter, for examples of acceptable conservation strategies and practices). Consolidation by pinning (with small stones inserted in to gaps in wall faces), pointing (with lime mortar introduced into gaps within wall faces), mortared (often with cement inserted into voids within wall cores) and supported (with steel or bronze bars or stone pillars supporting lintels for example) are visible in the Historic Environment Scotland *Properties in Care* and in other brochs. While we would not now wish to see these practices promulgated, they have arguably preserved the monuments involved until wiser counsels could prevail. However, some of the Historic Environment Scotland PIC (Properties In Care) brochs have been substantially altered from their original or authentic forms by aggressive conservation, unreliable or zeitgeistic reconstruction and by ongoing maintenance (see MacKie re Carn Liath; MacKie 2007: 638–9, or Brian Smith forthcoming re Clickhimin, for examples). While some records of these acts are contained in the PIC records, they are neither easily accessible to the public and to scholars alike nor in any instance a complete record of the pre- and post-interventions states of the monuments. Hopefully, any ongoing or future interventions will be more fully documented and more accessible to all.

Recent engineering research into the structural behaviour of the original broch form and its specific failure mechanisms, in its original, intermediate and current state, has been undertaken at the University of Edinburgh. The study also investigated potential drystone wall repair methods, using *Drystone retaining walls and their modifications – condition appraisal and remedial treatment* as a guide, where relevant (CIRIA 2009). Two methods proved relevant on this site, the replacement of selected stone within the wall and the underpinning of unstable masonry by bedrock-anchored steel rods (see Theodossopoulos et al 2012). While further work is required – and will always likely be undertaken on a case-by-case basis – the example of masonry consolidation at Clachtoll broch (discussed below) highlights the relevance of relatively unobtrusive drystone repair and the importance of detailed archaeological measured survey before and after conservation interventions, an approach for which laser scanning is ideal.

While archaeological measured survey can greatly enhance effective academic analysis and discussion – and can play an important role in considered conservation management – it can also be used to enhance and inform public interpretation. The presentation of our cultural heritage through public interpretation has been widely discussed elsewhere, most usefully in this context by Lesley Macinnes (1991: 209–15), who includes the concept of promoting the care and conservation of archaeological sites to land managers. Using archaeological measured survey to illustrate a site – particularly within site-based interpretation using a constructivist learning approach (Merriman 2002: 549) – can encourage a broader understanding of the original and authentic archaeological remains of the monument (and a greater appreciation of similar features at other sites) in a way that simple artistic reconstruction drawings cannot. Good archaeological illustration consolidates learning and understanding by encouraging the active participation of the reader.

BROCH DIAGNOSTICS AND METRICS

Each broch structure is an amalgamation of sub-structural elements, the entrance passage, or guard cells or stairways, for example, these are referred to as substructures in the following text. Several broch substructures contribute to our understanding of the original forms of the broch and are capable of providing an insight into the intentions of the builders, almost irrespective of the level of survival of the site as a whole. However, the condition of the surviving brochs is generally a major limitation on the dataset. Of the roughly 600 brochs and probable brochs listed in Canmore, only *c* 150 display any features whatsoever and in only *c* 80 cases are there sufficient features visible to facilitate further analysis. Variability in the quality of recording is one of the principal limitations of the existing, restricted surveyed dataset. However, and as noted above, the more successful broch surveys have adequately reproduced structural details, even where their full structural significance has not been initially appreciated.

Construction of a stable high tower in loose fill material, with rubble contained between facing walls, gives rise to hydrostatic-type pressure on the retaining walls that can quickly bring the structure to crisis. If the building stones are laid horizontally, one on the other, throughout the thickness of the wall, that force is reduced to zero. Thus, horizontal placement of the building stone may also indicate the intent to construct a high wall, or, more correctly, the absence of horizontal placement of the building elements between retaining walls is a counterindication for tower construction. Thus, Whitegate broch in Caithness, for example (illus 1), was not intended to be and could never have been a tower.

Broch masonry is uncoursed, but the stones are normally set with their latest faces in the horizontal plane and with maximum stacking density, ie the minimum of airspaces between them. Clearly, the creation of a scarcement ledge requires that the inner broch wall be brought to a level, so that the ledge can, similarly, be levelled. At Clachtoll, it was clear from survey that a level exists in the entrance passage area at which the base of the outermost lintel, the base of the lintel to the guard cells and the top of the bar hole and receiver openings are placed. Observations elsewhere show some of these features above and some below the putative level, but the principle seems preserved. Subsequently, when the

Illus 1 The wall of Whitegate broch, Caithness, comprised rounded beach cobbles retained by facing blocks and could not have been intended to carry the weight of a tower-like superstructure

entrance area of Clachtoll broch was modelled at 1:1, in Spittal quarry (Barber 2011), it became clear that the insertion of the bar hole required that this levelling extended into the wall fabric, to accommodate the long bar-housing, to contain the bar that secured the door. It is suggested here that horizontality of local stone placement and level control across the structure were finely developed in the broch towers, over the entire diameter of the wall circuit and at all heights. This is consonant with the structural desirability of not creating sloping planes in the masonry along which slippage and structural cracks could progress. Close control of stone horizontality and building plane level, even in the wall core, are therefore promoted here as further criteria indicative of the intention to construct a tower because there is otherwise no need to incur the skill- and material-costs involved in exercising that control.

Illus 2 The infilled gulley beneath Thrumster broch: a rare example of prepared foundations for a broch wall

The most eloquent display of horizontal control is given in those cases in which the broch structure rises from significantly uneven ground surfaces. It should be noted that there is little or no evidence for the construction of formal foundations for brochs or broch-like structures, including broch towers. The observation of an infilled gully under the broch base at Thrumster (illus 2) is quite exceptional and nothing resembling a constructed foundation extended beyond the narrow confines of that gully. There is a very real sense in which the ground floor of a broch tower is its foundation.

The surveyed brochs at Caisteal Grugaig and Clachtoll both spring from profoundly uneven ground levels with differences of 3m for the former and 1.5m for the latter between the highest and lowest ground footings on the site. What is truly remarkable in both instances is that the inner wallface is very closely circular at, and above, the level at which the full circuit of the wall is united. The implication of this observation is that, as MacKie's definition suggest, true or orthogonal circularity was a *desideratum* of the builders and that the prevailing skillset was adequate to allow for the construction of isolated elements of the walls in the confidence that they would be orthogonally circular when they merged. This goes directly to the issue of the quality of the build and the question over whether such a project was within the capabilities of farming communities without the input of specialist architects/master masons. The existence of elliptical interior plans (see below) would seem contra-indicative of this criterion, but it is necessary to ensure that the eccentricity has not resulted from failing to survey in a truly horizontal plane. Thus, in the commissioning of such surveys, a demonstration of level control in the survey should be required henceforth.

3D RECORDING TECHNIQUES, SURVEY AND OBSERVATION: FIELD AND POST-SURVEY METHODS

Given the three-dimensionality of broch structures and the metrical controls required for meaningful analysis of their structure, recent developments in the application of high-resolution 3D laser scanning to archaeology have become very relevant. Laser scanning provides a means of acquiring large quantities of 3D measurements of a structure in a short space of time. Terrestrial laser scanning technology developed very rapidly over the past decade, meaning that modern scanners are capable of surveying 360° and overhead, even in the confined spaces found in the intramural galleries of brochs. A typical field workflow would comprise the laser scanning of a broch from numerous survey stations within and around the monument, with positional control provided by a network of reference targets established using a total station. Using this same coordinate system, the site-interpreted detail of the structure was recorded in a traditional point-by-point manner using the total station, and this linework is used in the office to guide the marking of wall faces and other features recorded in the scan data, with the actual stones in the 3D data used as the guide for drafting. This combination of techniques allows the investment of the 3D scan with the interpretation of the surveyor, but avoids the uncertainty and subjectivity of the choice of placement of each measurement point by the surveyor in the field (above).

One of the principal advantages of laser scanned data for brochs lies in its ability to produce cross sections and orthographic views of scanned elevations. 3D data can be cross-sectioned in any dimension, meaning that accurate measurements for the profile of corbelled cells and their position within the walls of brochs can be produced. Filtering techniques can also allow data to be presented orthographically and colour coded by elevation, so that two-dimensional views can convey all three dimensions of the structure (see Caisteal Grugaig, below), with the advantage over a developed plan of being able to show voids, wall batter and overhangs accurately.

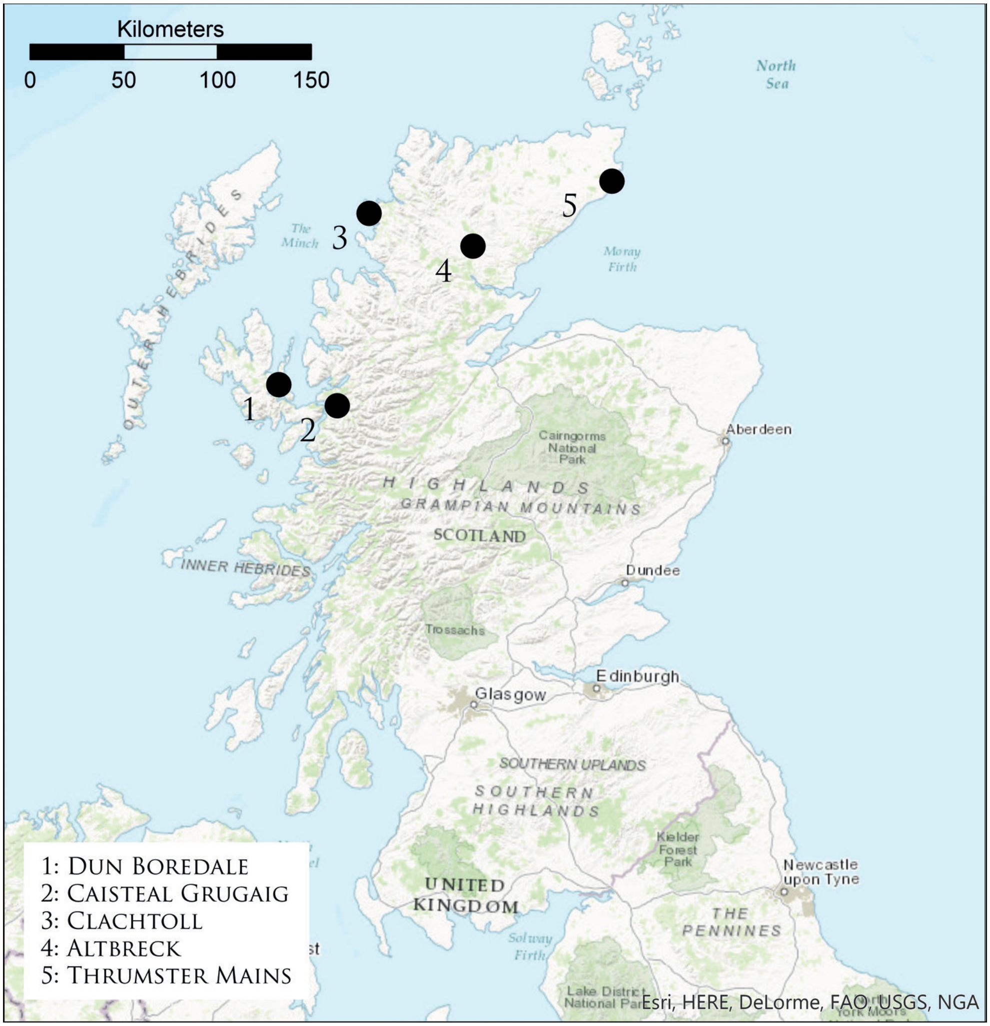
Control of levels is essential to the 3D recording of broch sites. As discussed above, the challenges faced by the builders of brochs in bringing walling to a level on very uneven and rocky prominences were considerable, and the relative heights of intramural spaces have an important bearing on understanding how broch towers were furnished internally. The capture of three-dimensional data, furthermore, allows meaningful comparisons to be made between apparently similar sites. While superficially similar on the basis of ground plan, when probable height, stone size and geology are taken into account, the levels of labour investment in the construction of apparently similar brochs can vary considerably. The assessment of volume is an essential component in the assessment of investment in broch structures; volumes of hollow walled circular towers are difficult to calculate based on ground plans and elevations, but laser scanned data makes this relatively straightforward.

CASE STUDIES

The structural condition of the brochs that survive varies greatly. Some are submerged in their own debris-fields while many have been robbed of stone over the years or incorporated into later settlement (for a fascinating regional study of survival and destruction, see Tait 2005). Many were cleared out in the 19th century and few have seen archaeological excavation, conservation or structural consolidation (although some brochs in the care of the state have been pinned and mortared to prevent further decay). As noted, we share MacKie's concern that many of the acts of conservation have not been recorded and that unsupervised maintenance of brochs continue to impose unrecorded alterations on the fabric of the monuments (see, for example, MacKie 2007: 639 and illus 7.302–4).

The following sites were among those recently surveyed using laser scanning, on behalf of Forestry Commission Scotland, for the purposes of conservation management planning, with the exception of Clachtoll, which was surveyed as part of a community archaeology project with Historic Assynt (illus 3). Each example illustrates the concerns set out above, with recording the details of broch construction and their relationships in all three dimensions, in this case pre-conservation, and this level of recording will also follow any proposed intervention.

Several of the sites were also recorded using low altitude vertical and oblique aerial



Illus 3 Location of sites mentioned in the text (© ESRI mapping)

photography, flown using a remote controlled microcopter equipped with a digital camera. The technique has proved remarkably adept at capturing images for illustration, site condition monitoring and for conservation management purposes, particularly in regard to upstanding masonry structures and large scale earthworks. The technique can be used to provide both detailed images and landscape setting (captured with 360° flexibility); and rectified vertical images can be used to support archaeological measured survey (illus 4).

CAISTEAL GRUGAIG

Caisteal Grugaig (NG 866 250) illustrates the value of the detailed survey of upstanding brochs using controlled, levelled laser scanning. The site overlooks Loch Alsh, Totaig, close to a steep-sided stream valley where it occupies a rocky knoll that has required the builders to accommodate changes of slope and bedrock height. The broch was cleared out in 1889 and was first recorded by Wallace (1897: 86). A measured survey was published by Angus Graham (1949: 12–24). The analysis of the

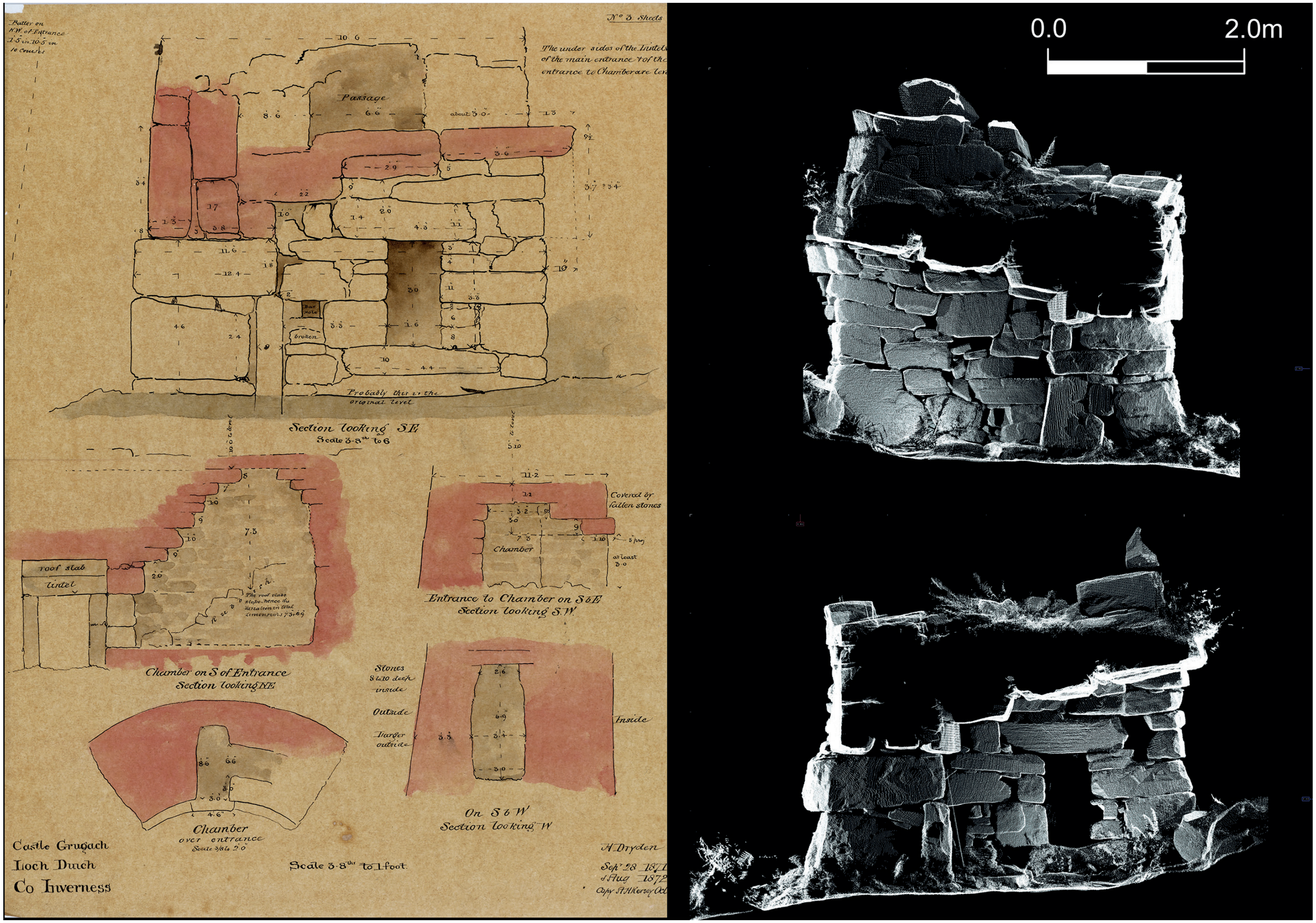
ILLUS 4 Low altitude vertical and oblique aerial photography uses a remote controlled microcopter equipped with a digital camera. This rectified vertical image captures the structural plan of Dun Suladale on Skye (NG 374 525)

structure and the relative position of the entrance passage, ground floor cells, scarcement and upper galleries provide a valuable insight into the complexities of the interior areas of broch towers and how they functioned, in addition to shining a light of the technical competencies of their builders.

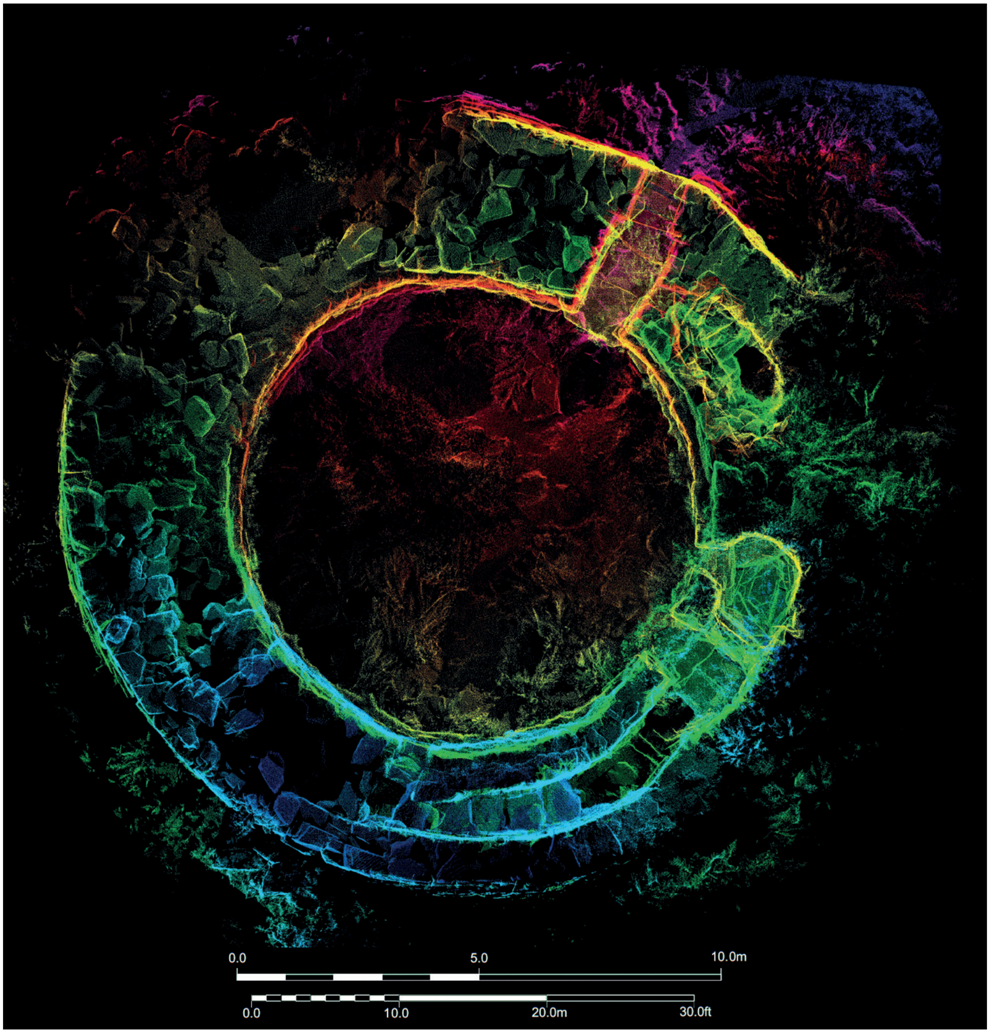
The broch is 'solid-based' in Mackie's terminology, ie not solid masonry, but not containing a continuous ground gallery either. The base of the structure houses four intramural cells that can be accessed from the current ground levels; Graham noted that the rocky knoll on which the broch is sited varies in ground level internally by some 5ft (*c* 1.7m) (ibid: 16). A partially collapsed guard cell is accessed from the left hand side of the entrance passage. Cell 2 (see illus 5 and 6) is complete and comprises a small cell accessed via a low doorway. Cell 3 provides access to the stairs leading to Level 1, the upper passage of which is still partially lintelled, terminating beside/just past a doorway giving access to the interior at Level 1. The scarcement which presumably supported the Level 1 floor and was accessed from this doorway. The scarcement is now far from level across the site, with a difference of over 1.1m between its lowest and highest points (illus 7 and 8; note that Graham has this as relatively level with one minor misalignment).

Graham's, and all subsequent interpretations of this monument, assumed that at Grugaig the ground floor of a standard broch has been, in effect, cut away to match the monument to the knoll on which it was built. This informed the brief given by two of us (JB and GC) to architecture students at the University of Edinburgh (ESALA), for a study of the broch.

Taken at face value, the differences in floor level invite a wide range of special pleadings in



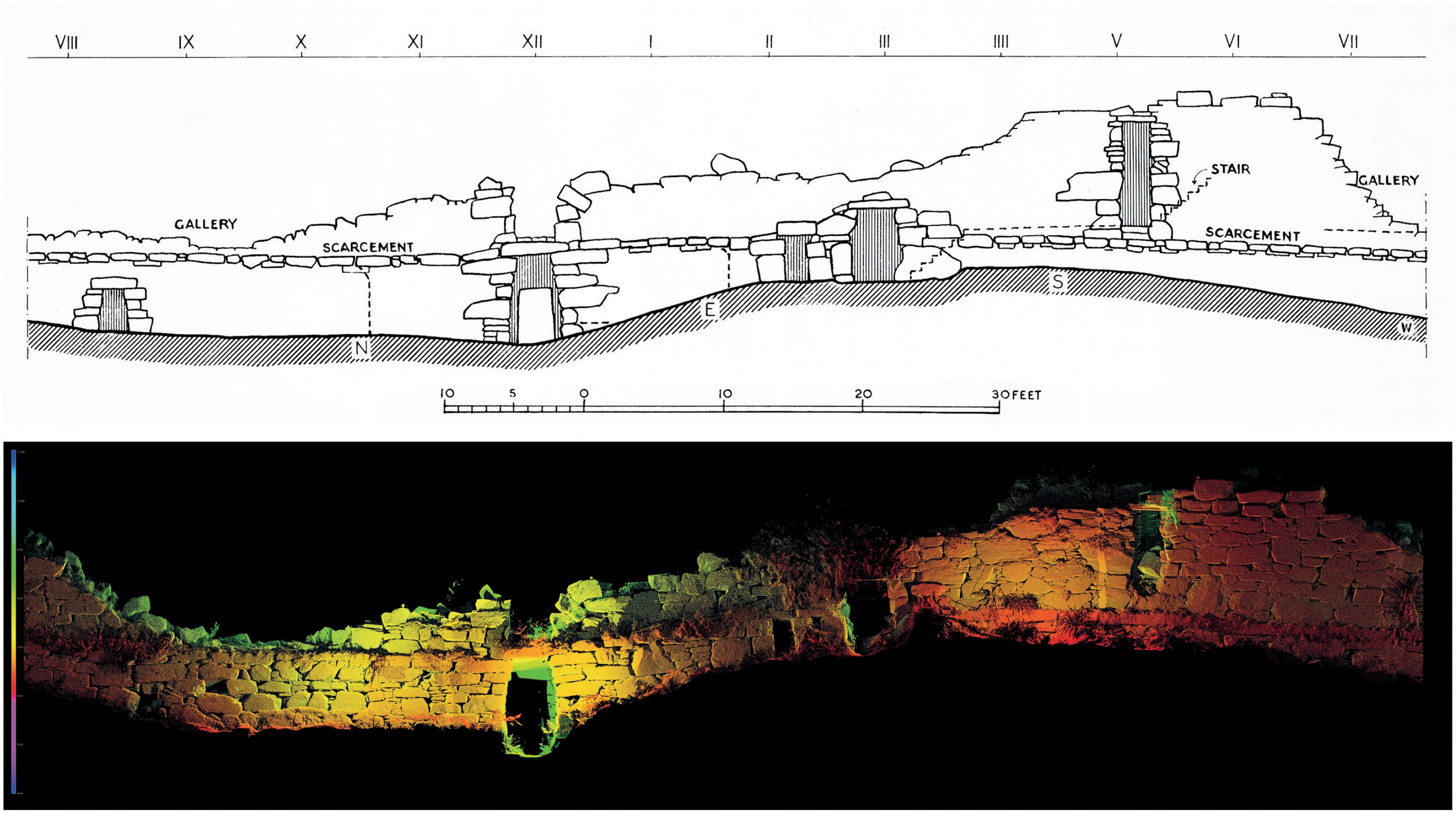
ILLUS 5 The broch of Caisteal Grugaig was the subject of several very attractive unpublished measured drawings made in 1871 and 1872 by Henry Dryden. He recorded the broch on plan and produced a series of annotated elevations and sections. This elevation of the south-east side of the entrance passage depicts the door check, barhole and guard chamber (presented alongside the corresponding point cloud elevations derived from the laser scan). (© Courtesy of RCAHMS (Society of Antiquaries of Scotland Collection). Licensor www.rcahms.gov.uk)



Illus 6 The orthographic plan of Caisteal Grugaig, derived from a laser scan, allows the depiction of the variable levels throughout the structure, and the position and heights of the intramural cells (purple/reds indicate low areas, light blue indicates high areas)

the proffered interpretations. Fojut has suggested that the scarcement at Caisteal Grugaig supported the roof (2005: 192), though in that scenario the purpose of the first-floor doorway is rather unclear. However, a hole has opened in the wallhead at roughly the 11 o'clock position through which a gallery can be seen to extent anticlockwise in the direction of the existing stairway. It is certainly deep enough to pass under the stairway. This implies that the ground floor of the broch is either not bedrock and extends lower than has been allowed or that, if the interior is an uneven bedrock knoll, that the outer wall of the broch is set outwith the limits of the knoll on the uphill side, allowing the insertion of a continuous or near continuous gallery around at floor level. If this view be accepted, then the ope over the scarcement is merely the lowest void of the stacked void normally found in association with broch stairways. In a similar vein, the small aumbry seems to us a secondary breach into the counter-

Illus 7 Caisteal Grugaig drawn plan and sections



Illus 8 Caisteal Grugraig. Above: The innovative 'elevation of the interior developed on the flat' produced by Graham (1949) remains a very useful illustrative style, highlighting architectural features such as the scarcement. Below: the equivalent image produced by 'unrolling' the 3D point cloud and projecting onto a flat plane (© Crown Copyright: RCAHMS. Licensor www.rcahms.gov.uk)

ILLUS 9 Plan of Clachtoll broch

stair cell that sits opposite the stairfoot in a 'standard broch'.

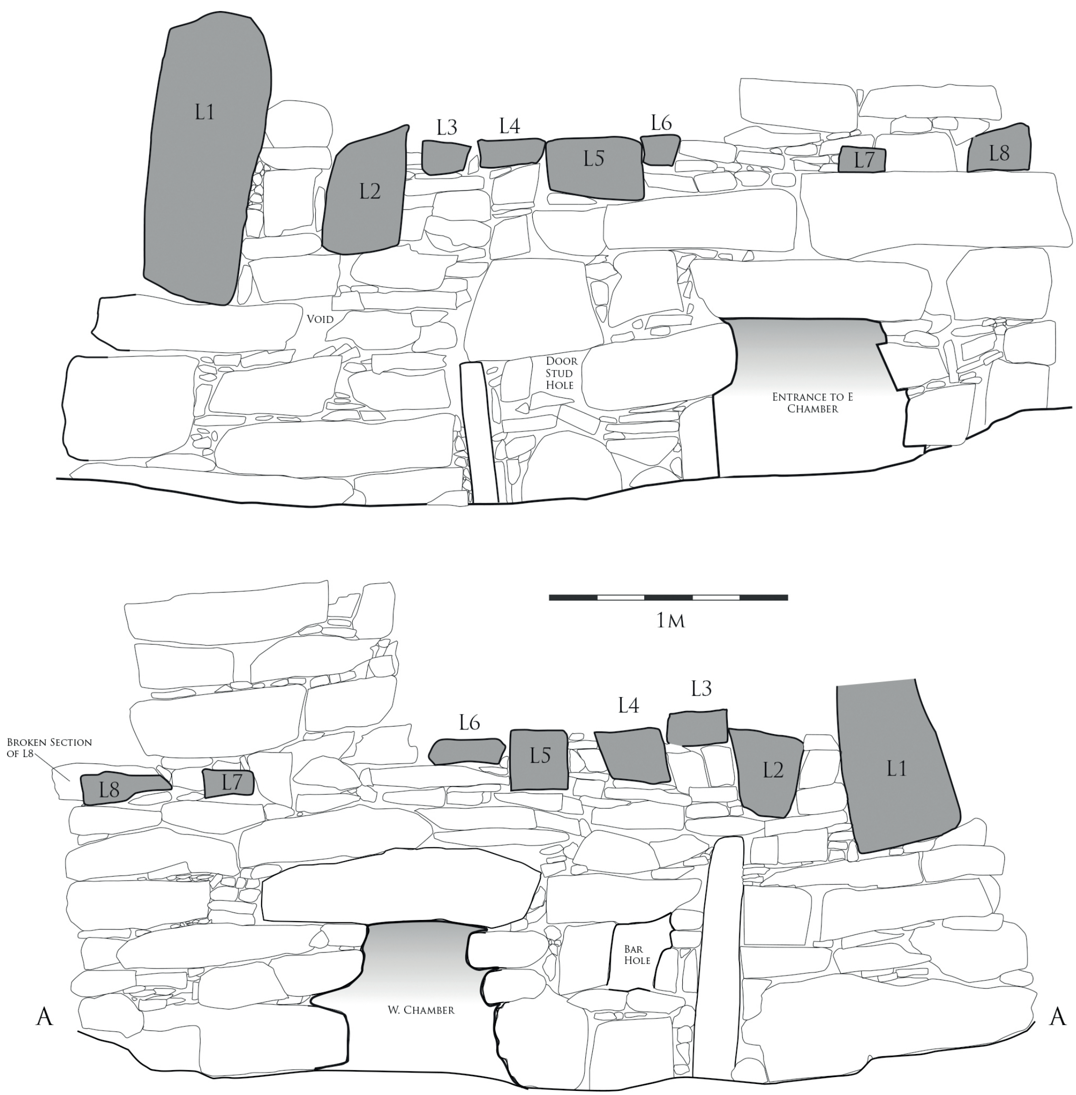
The assumption that the garth (space within the broch wall) floor was composed of bedrock has strained our interpretations of Dun Grugaig. If it is not bedrock or if that bedrock is limited literally to the garth with the wall structure wrapped around the rocky knoll, as the recent observations suggest, then the paradoxes of this monument are removed and it can be reinterpreted as a fairly standard broch. This interpretation is eminently capable of test, by simply sectioning the intramural void, or the adjacent deposits inside or outside of the broch wall opposite the entrance.

CLACHTOLL

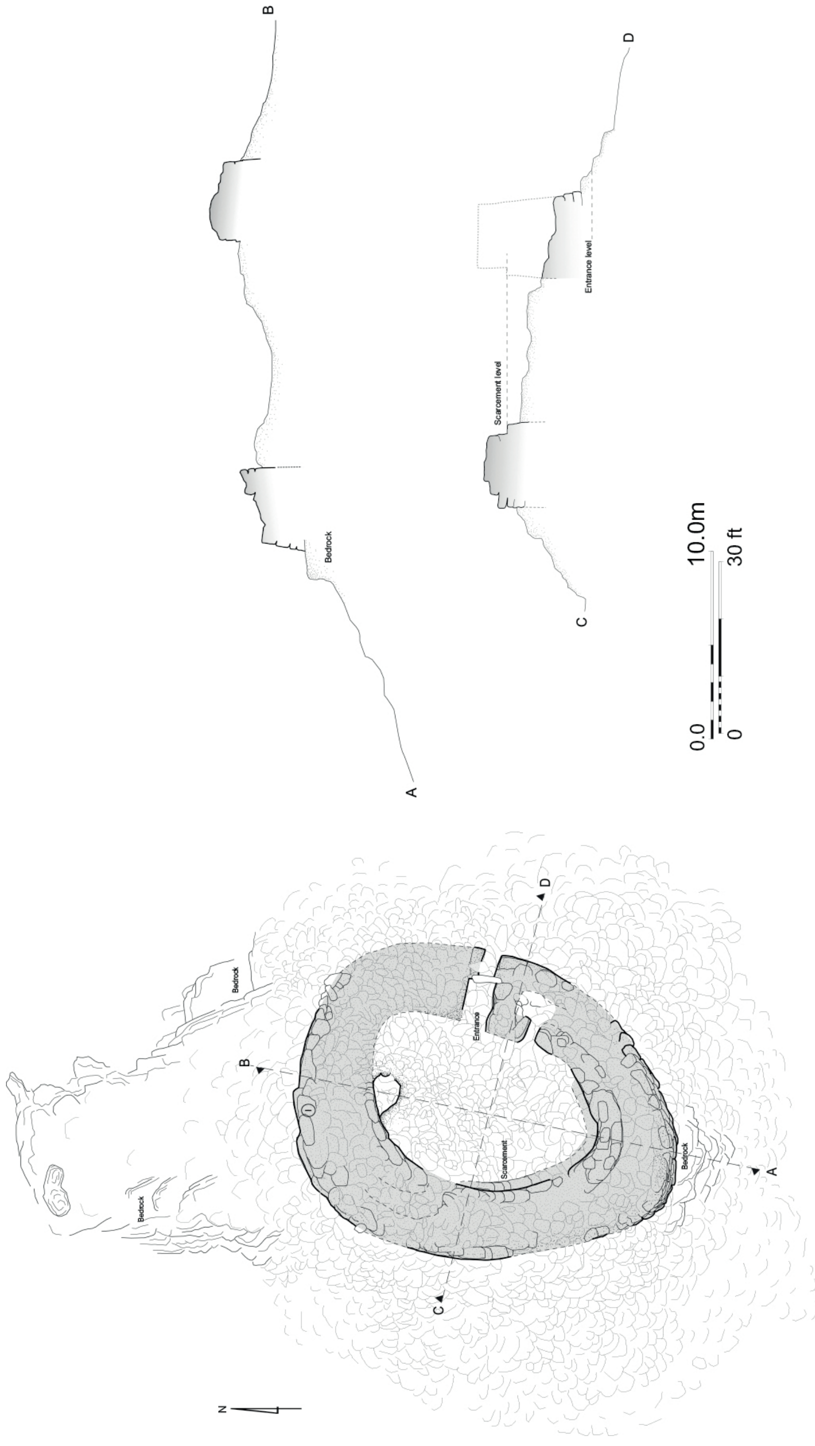
The broch at Clachtoll (NC 036 278) lies on the north-west coast of Assynt, Sutherland. It is sited atop an irregular outcrop of Torridonian sandstone, from which rock type its construction materials are largely drawn. Although above the MHWS line, the broch is affected by storm surge waves at spring tides. Its western third is greatly reduced and, over a length of *c* 8m, has been removed entirely.

The broch wall at ground floor level contains four cells (illus 9), two guard cells entered from either side of the entrance passage, a side cell and a stairwell. The side cell, on the east, lies at the point at which the ground level is lowest and measures some 3m high, its apex being roughly level with the bedrock revealed by marine erosion on the west. Thus, the floor level on the east side is some 3m lower that the floor level on the west. Above the ground floor level the disordered remains of a gallery can be discerned, extending over the entrance passage, and its side walls survive to over 1m high.

There were probably 11 lintels over the entrance passage of which eight survive. The two outer lintels taken together form a compound beam structure designed to cope with loadings



Illus 10 Elevations of the entrance to Clachtoll broch



Illus 11 Plan and sections of Dun Boredale, Raasay

associated with the mass of the thick outer wall. The outermost, a triangular lintel (L1), forces the wall mass to corbel either side of it. Between this and L2, the next lintel, a gap some 300mm wide occurs into which a corbelled arc has been built across the passage. L2, a massive stone, is set with its longest cross-sectional dimension in the vertical plane; it is edge-set. Lintels L3, L4 and L5 are also relatively massive. Re-excavation to the tops of the lintels for conservation purposes (Barber 2011) revealed an arrangement interpreted as provision for an upper set of lintels. Whatever the details of the original arrangement, it was clearly intended that the outer five lintels should carry the mass of the outer wall. The inner lintels were flattened slabs of limited carrying capacity (illus 10).

Reference has been made above to the irregularities (spread vertically over 3m) of the bedrock onto which the broch was built. The laser survey revealed that at the level at which a continuous circuit was established, the inner wallface was truly circular with deviations from circularity near the minimum possible in fitting a polygon (of side lengths equivalent to the average stone length), into a circle. The builders were clearly capable of building to an orthogonal circular plan from a dissected, irregular rocky base.

Clachtoll was a broch tower because it meets all of the MacKie criteria and, in addition, provides observable evidence interpreted as reinforcement of the outer passage lintels by the creation of a compound beam of great strength; a feature with no justification other than that of bearing great loading.

DUN BOREDALE

Dun Boredale on Raasay (NG 554 363) is an example of the generic Atlantic roundhouse class of later prehistoric settlement, although typically for the Inner Hebrides and southern mainland of the Atlantic region, the site is not perfectly

ILLUS 12 Dun Boredale, unrectified vertical low altitude aerial photograph

circular, rather forming an irregular oval plan, so that the site has tended to be considered a 'dun' rather than a true 'broch' (illus 11 and 12). Dun Boredale is not, therefore, a broch tower as defined by MacKie (above).

MacKie considered the site in his corpus of the brochs, wheelhouses and roundhouses of Atlantic Scotland (2007), paying particular attention to analysis of the structure and the reconstruction of the wall features. He states that Dun Boredale should be classed as a broch, '… though an oval one, ... the conjunction of a scarcement ledge, a doorway of appropriate design and signs of an intramural gallery on the wallhead above the scarcement would normally be quite sufficient to confirm its nature' (2007: 845). The strict logic of taxonomy must exclude this monument from the class of broch towers, not least because MacKie himself has posited circularity as a discriminant for the class of broch tower. That it has deployed some of the substructures characteristic of broch towers, however, is beyond question.

MacKie established in 1985 that the scarcement ledge was level around the circuit of the wall, though he noted that due to the uneven nature of the bedrock foundations of the site the ledge is considerably below the level of the basal course of the outer wall face to the north, and in this respect it may be compared with the broch at Clachtoll (above). It is possible that the natural bedrock outcrops were used to accentuate height, particularly in the elevation above the entrance (which is often on the lower area of such sites). However, as Grugaig also demonstrates, the assumption that the solum is bedrock requires clear demonstration before its impact on the tectonics of the monument are addressed.

The irregular shape of Dun Boredale and its differential levels of survival illustrates the challenge for the production of accurate survey drawings. In this instance, the laser scan data was used to produce a developed plan, showing the batter of the external wall face and the relative position of the upper gallery and ground level mural cell (see illus 11).

Mackie deduced (2007: 845) that Dun Boredale is sited on steeply sloping bedrock, with the level of the outcrop to the north of the wall roughly 5m above that at the entrance passage (see illus 11). Although the bedrock cannot be traced in many places other than at the northern and southern extremities of the monument, the height difference that had to be overcome during construction was considerable. The decision to place the entrance at the lowest point on the putative knoll may have been a deliberate accentuation of the front elevation above the entrance passage. The scarcement ledge is *c* 1m below the level of the bedrock on the northern outer wall face, and projecting this level across the site indicates that the first floor, if projected from the highest bedrock level, must have been at least 4.5m above the entrance passage floor level. Allowing for the upper galleries suggested by the remains on the wall head, it seems likely that at least a further 2.5m of upper walling has been lost from the highest surviving wall head. Again, projecting this level across the site leads to a total wall elevation of around 9m above the entrance passage, so that Dun Boredale, while eccentric, was a tower. Its closest morphological relationships are thus with the broch towers, a group from which we have suggested its eccentricity excluded it. Its builders, a term that includes the commissioning agent, the master-mason or architect-surrogate and the building labourers and masons, were clearly cognisant of the constructional parameters of broch towers and tried to emulate them. The implication is that the builders' primary concern was with accommodating the precipitous footings of the building, so that the otherwise broch-like architecture had to be accommodated within an irregular ground plan by necessity. This observation is instructive, since the requirement for the circularity of the structure was apparently conceded in favour of the location and the requirement for tower-like stature. It is possible that topology limited its potential, and while its builders were not daunted by the pronounced irregularity of its bedrock founds, they were nonetheless unable, or unmoved, to bring it to a truly circular form.

ALTBRECK

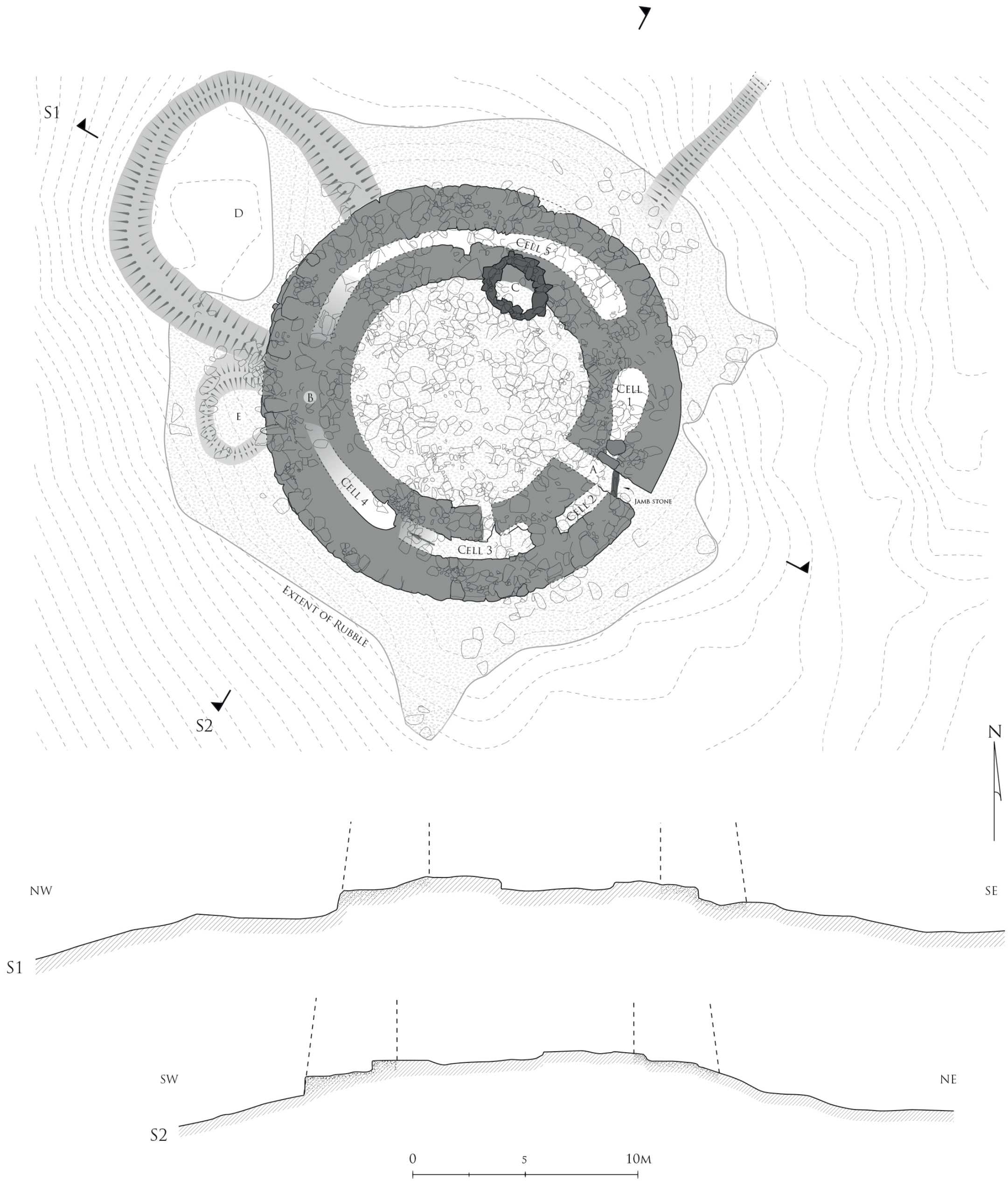
The remains of Altbreck broch (NC 591 103) are particularly interesting because they are now on the cusp of becoming meaningless to surface appraisal, but they have been surveyed when in a rather better condition by the Royal Commission for the 1911 Inventory. The writers examined and undertook a laser scan survey of the monument and its immediate setting in 2013 (illus 13). The Forestry Commission had supplied a copy of the plan and associated text of a recent survey which had been undertaken by operatives apparently innocent of the RCAHMS survey, and of its interpretation by Romankiewicz (2011, Vol II: 207). Original or authentic features which are at the point of final dissolution were interpreted in the survey from FCS, as modern rearrangements of the fallen masonry, an approach no doubt influenced by the existence of one clearly recent shooting butt which straddles the inner wall of the broch at the 3 o'clock position.

The site is a heavily robbed broch, sited on a naturally terraced east/west knoll, overlooking rolling topography, with Loch Shin to the west. The structure comprises a roundhouse with walls averaging *c* 3.8m thick at current solum, circular in plan and measuring 18.5m in external diameter and 10.9m internally. The entrance is aligned to the south-east and forms a passage 3.5m in length and *c* 0.8m wide. The passage is choked with rubble, but a large slab, now fallen into the passage 1m from the outer wall face, indicates the presence of a door check. Two intra-mural cells were accessed from the entrance passage. Cell 1, to the north of the entrance, forms a guard cell, the west side of which is partially corbelled and survives to a height of 1.2m above the rubble surface. Cell 2 was also accessed from the broch entrance passage, with the entrance to that cell directly opposite Cell 1. Cell 3 probably accommodates the stairs and is accessed via an entrance passage from the broch interior. Cell 4 is visible as a round-ended, partially corbelled return within the thickness of the wall; the cell is ruinous and rubble filled, but may continue to the west. The western portion of the broch is ruinous and much disturbed, although the rubble between the inner and outer walls is vacuous and may suggest the continuation of Cell 4. Cell 5 is visible beginning in the north-west quadrant of the wall, running through much of the north side of the broch wall. It is possible that Cells 4 and 5 are parts of the same segment of a gallery.

Mackie has suggested that the monument is not circular, but markedly elliptical with major and minor axes of 18.61m and 15.86m, contra RCAHMS 1911, who render the monument as a circular one. Mackie is an acute field observer and his account merits exploration, since the laser scan suggests that the monument is in fact circular. The averaged plane of the monument's erosion lies at slightly less than 5° to the horizontal. If the broch had been a right cylinder, this oblique cut would yield an elliptical form, measured on the erosion surface, but the axes would differ by a mere 60mm, not the 2.75m that Mackie implies. However, the broch is not a right cylinder, rather, where measurable, its outer face inclined inwards at *c* 25°. This would reduce the measured horizontal diameter by 92cm for every metre of height. Across the diameter at present, the difference in height between the highest and lowest wallheads is 1.45m. Pro rata, this would lengthen the major axis diameter by *c* 1.33m given the current erosion plane. Thus, simple diameter measurements in the erosion plane can vary from truly circular to elliptical shapes with eccentricities of up to approximately 1.5m in current circumstances. When examined by MacKie in 1963, the highest surviving parts may have been higher than they now are and this alone may account for his interpretation of the plan as strongly elliptical. This brief exegesis is included here to emphasise the significance of the third dimension in all broch metrics and the near irrelevance of the external diameter measurement.

CONCLUSION

This paper has attempted to demonstrate the importance of analytical survey to the interpretation of broch architecture, with consequences for our understanding of Iron Age society in Scotland. Building on over a century of broch recording, the analysis of structural details in surviving broch remains can now be expected to lead us to a clearer understanding of the original nature of upstanding broch sites and, by proxy, of the levels of technical



Illus 13 Plan and sections of Altbreck

skill involved in their construction. Functional analyses such as those offered here are essential to an understanding of the intentions of the builders and, thereby, to the perceived role of brochs in Iron Age society. Furthermore, and as with all classes of archaeological monument, better understanding is an essential prerequisite to appropriate management, care and preservation.

By commissioning laser scan surveys of significant archaeological sites on the national forest estate, Forestry Commission Scotland aims to support the Scottish Archaeological Research Framework recommendations by 'promoting *the range of benefits and uses of laser scanning'* (ScARF 2012) and to contribute to the dynamic narrative of our national historic environment records. This paper aims to set such laser scan surveys in context by focusing on their benefits in regard to an important monument class: the broch tower, and undoubtedly they have a role in the recording of any other type of upstanding monument.

NOTE

1 MacKie has observed the significance of the large outer lintel; Barber here argues for a composite relieving structure involving all the lintels outwith the circuit of the gallery and a corbelled arc over them, which creates the 'cell' often noted by MacKie.

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