Towards a Total Archaeological Record: Terrestrial Laser Scanning and Archaeological Recording at Keiss, Caithness, Scotland

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Abstract
Developments in terrestrial laser scanning technology over the last decade have allowed high precision survey techniques to become much more commonplace in archaeological fieldwork than has ever previously been the case. These new techniques have led to a radical shift in what is possible in terms of detailed recording, and archaeological records are now much more easily integrated with 3-dimensional models of physical remains. The progression in technology is not free from difficulties, however, and the full integration of archaeological data raises theoretical as well as practical issues that must be addressed as part of a new paradigm in archaeological recording standards. This paper explores some of these issues, based on recent archaeological work in Caithness, northern Scotland, involving terrain modelling, narrative topographic survey and excavation recording. The methodology of constructing a detailed geodatabase is scrutinised, as are the challenges surrounding the integration of multiple data sources including laser scanned point clouds, GPS and total station data, and traditional records. This illustration provides the basis for an examination of the aims and standards of archaeological recording that should now be expected, as well as for a critique of taking an integrated approach to digital recording in field archaeology.

Keywords
Laser scanning, GIS, CAD, excavation recording, survey, brochs, Scotland

1. Introduction

This paper presents the results and ongoing work of a programme of archaeological survey carried out as part of a wider archaeological research programme in Caithness, northern Scotland (*Fig. 1*). The survey focussed on a series of 'broch village' complexes and their related archaeological landscapes on the east coast of the county to the north of Sinclair's Bay (Heald and Jackson 2001). Broch structures can most simply be described as drystone round towers, built primarily as houses during the Iron Age but continuing in use as focal points for settlement well into the historic period. While their form is relatively simple their engineering and architectural sophistication is not trivial. They comprise a massive dry-stone built wall containing intra-mural galleries and a range of features designed to allow them to achieve monumental proportions; well preserved examples survive to over 13m in height. Their scale amplifies the already vexed problem of relating their internal and external deposits to standing structures and the debris of their episodic collapse, much less the complexities of their reuse over time. In consequence, the interpretation of their remains and most particularly of their deposits during excavation can present a considerable challenge, and one which requires the use of carefully considered recording strategies. A central aim of the archaeological work discussed here was to incorporate a recording methodology that embraced new techniques, aspired to move beyond traditional recording methods towards a more holistic and complete documentation, and to make full use of the spatial component of the archaeological data recovered from both pre-disturbance and excavation survey.

1.1. Rationale: a total archaeological record

The survey work at Keiss had four main aims: 1) to create a pre-disturbance condition record of the sites; 2) to provide an integrated spatial database to assist in the analysis and interpretation of excavated data; 3) to preserve the three-dimensionality of archaeological data retrieved; 4) to produce an interpreted survey of the sites' cultural landscape. Broch excavations involve the interpretation of complex three dimensional stratigraphy, while the unexcavated structures themselves often allow detailed chronological interpretation based

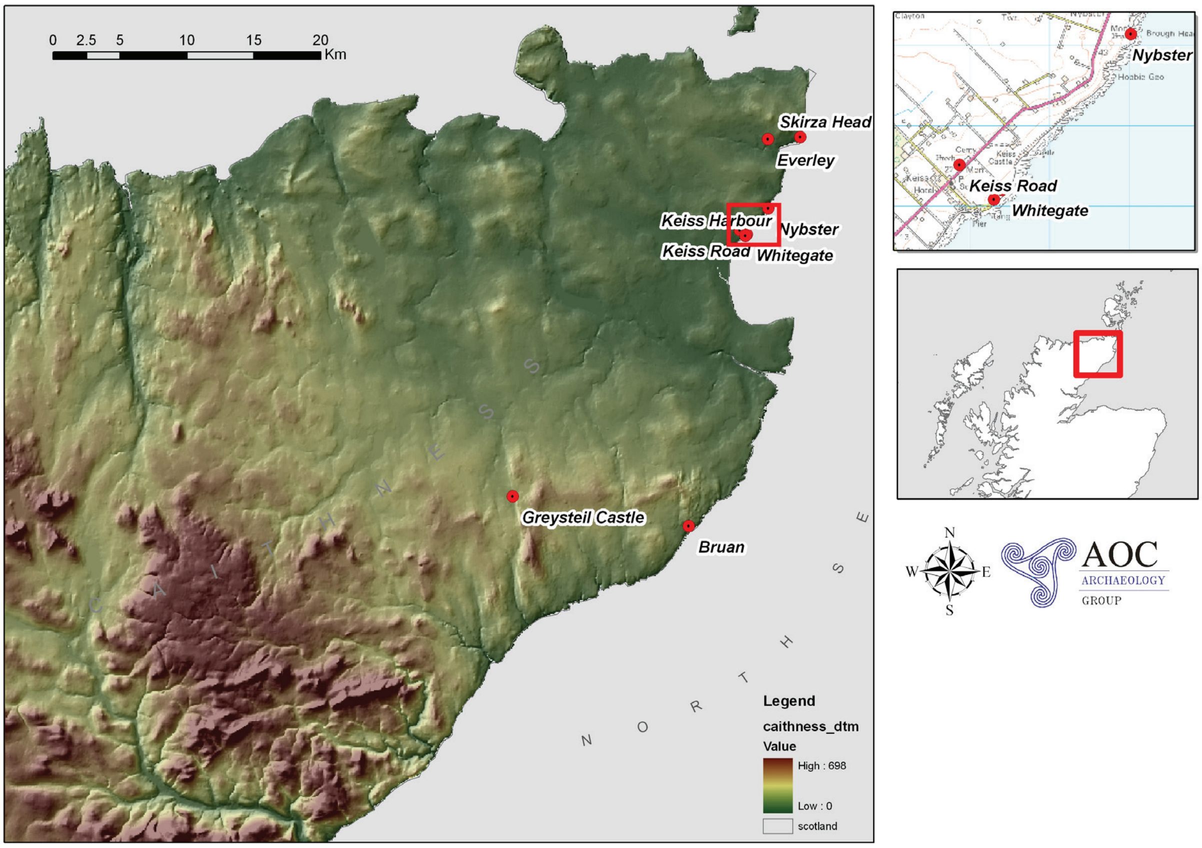


Fig. 1. Caithness, Northern Scotland, showing location of the study area.

on relationships between exposed wall faces. As such, Caithness constitutes the ideal place to implement a recording strategy that goes above and beyond traditional methods, while the controversy surrounding the interpretation of broch stratigraphy provides enough of an impetus to stimulate working towards this goal.

The essential rationale of the survey programme in Caithness is to provide a real-world coordinate to any single unit of archaeological data, and thereby to provide a spatial reference to any given relationship under consideration during the interpretation of the archaeological information collected. Central to this aim is the concept of a simultaneously "objective" and "interpreted" record and the aspiration for as close to a repeatable archaeological investigation as possible. This has implications for the philosophy behind the field methodology of archaeological recording, and we will return to this point. GIS provides the essential data structuring environment, and as a methodology, now has a well established theoretical and procedural framework for dealing with multi-scale 3D archaeological data (e.g. Ionnidis *et al.* 2002; Wust *et al.* 2004). The system used for the majority of GIS work in this project was ESRI's ArcGIS 9.2.

2. Integrating survey methodologies

The survey work was carried out at 3 levels of scale: landscape level, site level and feature level. A range of survey techniques were used, with laser scanning employed in order to capture the three-dimensional data.

2.1. Landscape level survey: terrain modelling

In order to build detailed terrain models, a Trimble GS 101 laser scanner running Pointscape was used to scan topography at a typical net XY resolution of around 100mm. The scan data was registered to Ordnance Survey georeferenced control – established using a Trimble S6 total station – using distance offsetting and direct reflex measurements to locate the registration target centroids. The resulting terrain scans were then edited using topography sampling algorithms in Realworks Survey and decimated for export to a geodatabase. Elevation rasters and TINs were then built using interpolation methods in the Spatial and 3D Analyst extensions for ArcGIS to provide 0.1m digital elevation models (*Fig. 2*).

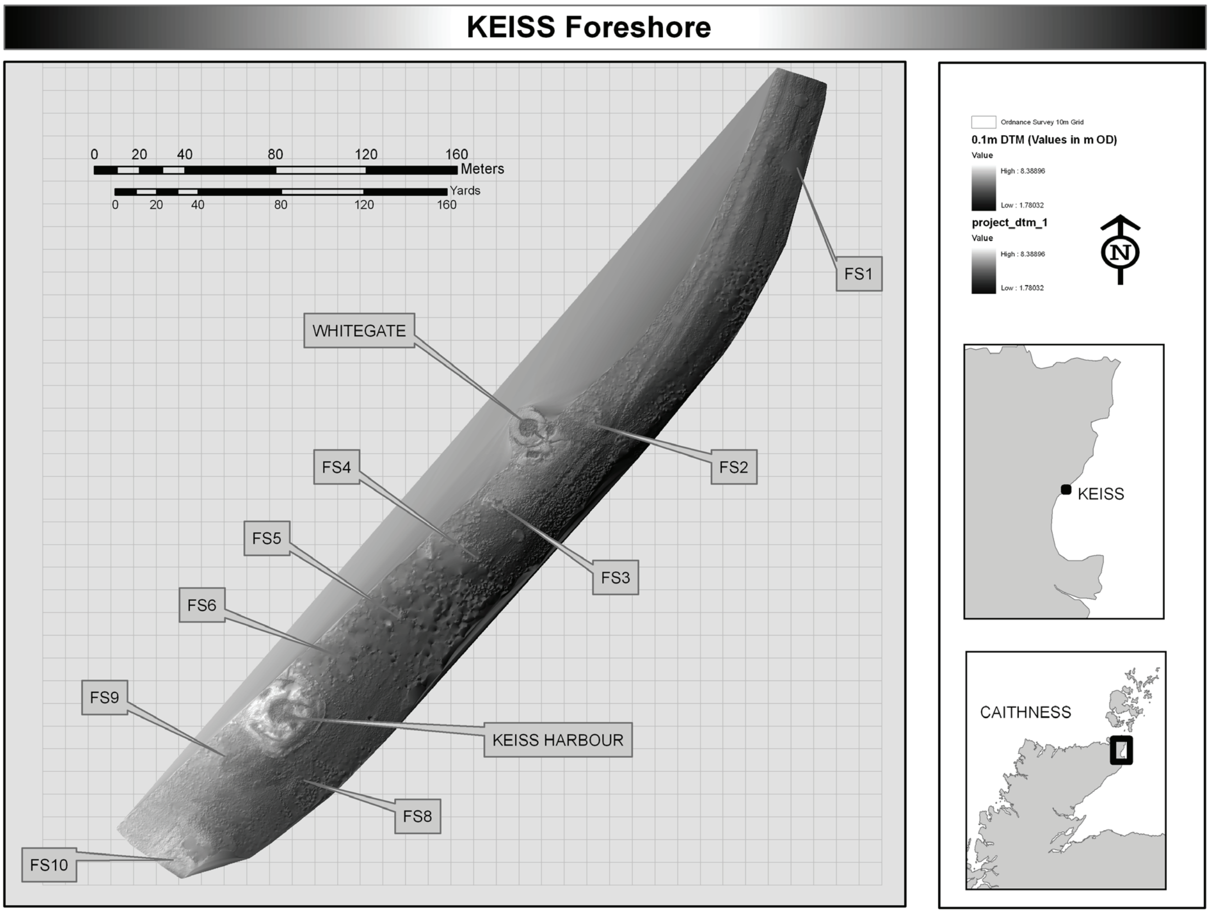


Fig. 2. 0.1m DTM of the Keiss foreshore.

Topographic survey was then integrated using survey grade GPS working with the same control as the terrain scanning. This allowed the incorporation of interpreted survey, layered and numbered using database building templates running on the field controller. Narrative photography was linked in to the database in the same way, using surveyed anchor points and database hyperlinks.

2.2. Site level scanning: interpretive survey

Brochs are very three-dimensional sites, and the aim of the site-level laser scanning, combined with Total Station survey, was not only the creation of a detailed record of the monuments in their pre-excavation condition, but also to record exposed architectural features and wall faces, thereby facilitating the stratigraphic interpretation of the complexes. Recording of the individual sites was carried out in a similar manner to the terrain modelling survey, but scanning at higher resolution to record the important structural features. Again, the same control network was used, allowing the integration of the data collected at site level with the landscape level survey. The scan data was exported to ortho-tiff, down-sampled for the creation of elevation models and again, interpreted survey and narrative photography were integrated into a GIS project (*Fig. 3*). Cross sections and elevation drawings were extracted from the scan data in AutoCAD to illustrate the interpreted phases of the sites based on field interpretation (*Fig. 4*).

2.3. Feature level survey: excavation recording

The third level of survey concerned the recording of excavation work. This is an application for laser scanning that has been widely experimented with since laser scanning technology became more readily available in the heritage sector (e.g. Doneus and Neubauer 2005a, 2006b). As mentioned earlier, the complex and highly three-dimensional nature of the deposits encountered on Scottish Iron Age dry-stone monuments makes them ideal sites for detailed survey of this type. The identification of the nature of the surviving deposits on Iron Age brochs is fundamental to their interpretation – it is normally assumed these sites are palimpsests of

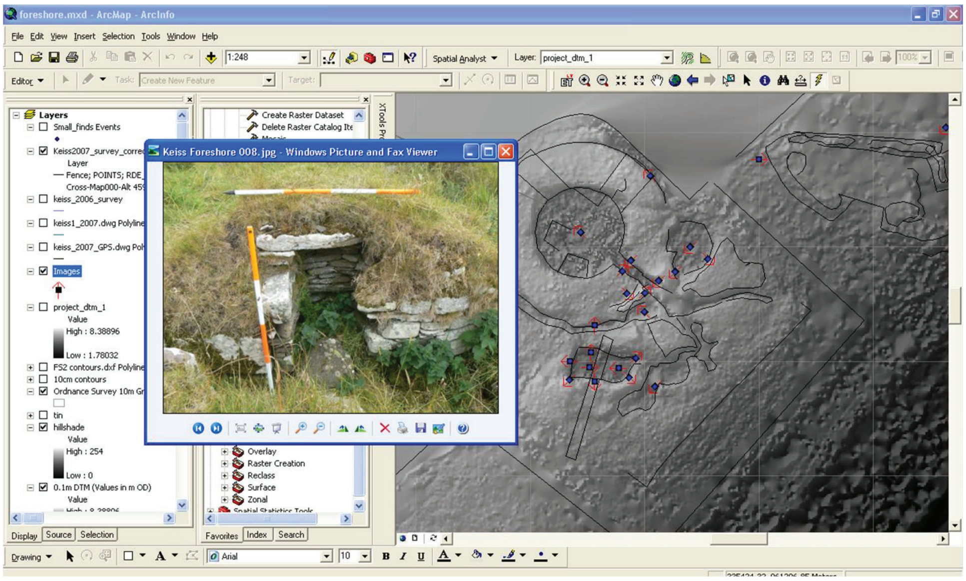
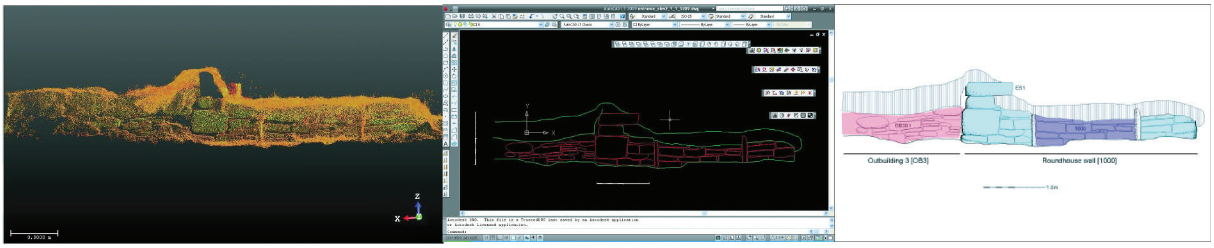


Fig. 3. Overlay of narrative photography, with imagery hyperlinked in GIS.



a

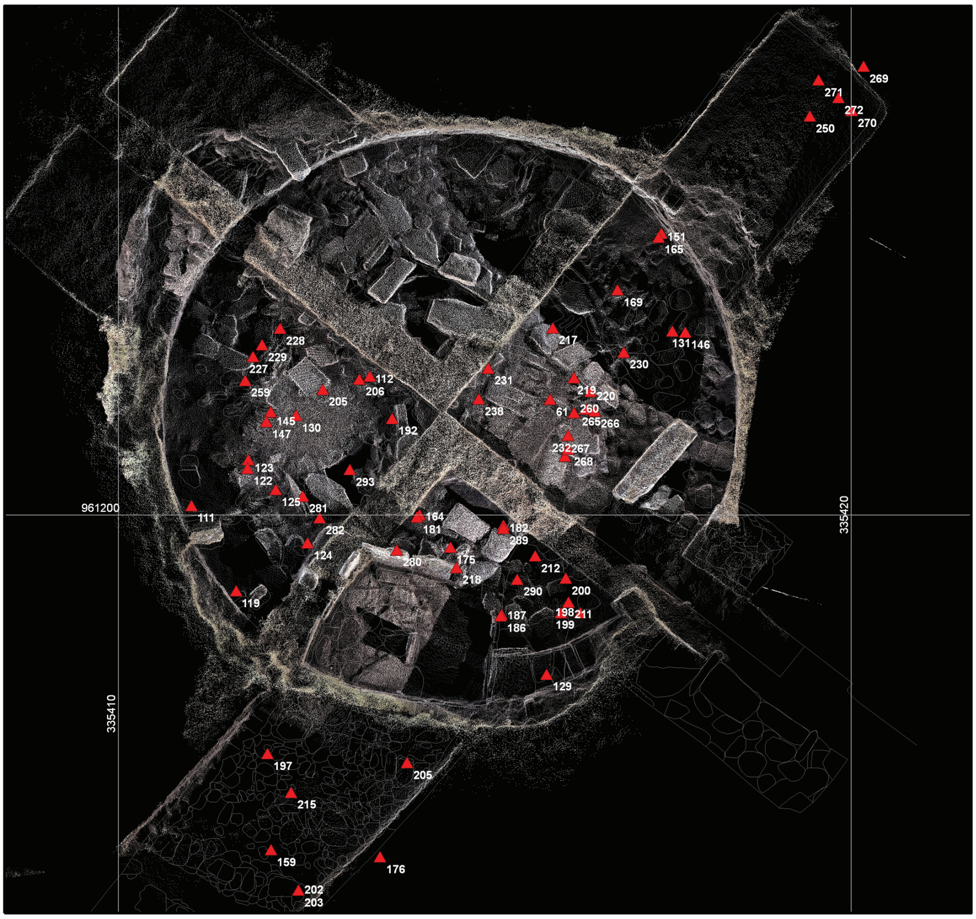
b

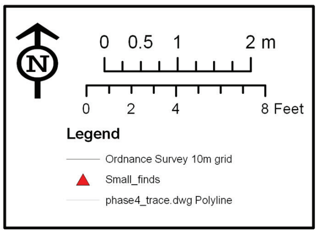
c

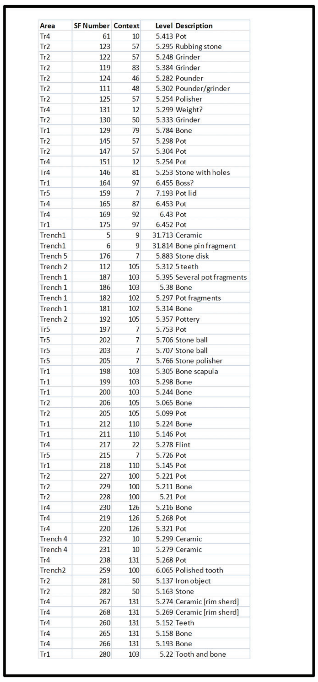
Fig. 4. Whitegate broch: a) pointcloud scan, b) extracted CAD elevation, c) marked up phased interpretation.

Fig. 5. Laser scanning the excavations at Whitegate broch.

WHITEGATE, Keiss







Area	SF Number	Context	Level	Description
Tr4	61	10	5.413	Pot
Tr2	123	57	5.295	Rubbing stone
Tr2	122	57	5.248	Grinder
Tr2	119	83	5.384	Grinder
Tr2	124	46	5.282	Pounder
Tr2	111	48	5.302	Pounder/grinder
Tr2	125	57	5.254	Polisher
Tr4	131	12	5.299	Weight?
Tr2	130	50	5.333	Grinder
Tr1	129	79	5.784	Bone
Tr2	145	57	5.298	Pot
Tr2	147	57	5.304	Pot
Tr4	151	12	5.254	Pot
Tr4	146	81	5.253	Stone with holes
Tr1	164	97	6.455	Boss?
Tr5	159	7	7.193	Pot lid
Tr4	165	87	6.453	Pot
Tr4	169	92	6.43	Pot
Tr1	175	97	6.452	Pot
Trench1	5	9	31.713	Ceramic
Trench1	6	9	31.814	Bone pin fragment
Trench 5	176	7	5.883	Stone disk
Trench 2	112	105	5.312	5 teeth
Trench 1	187	103	5.395	Several pot fragments
Trench 1	186	103	5.38	Bone
Trench 1	182	102	5.297	Pot fragments
Trench 1	181	102	5.314	Bone
Trench 2	192	105	5.357	Pottery
Tr5	197	7	5.753	Pot
Tr5	202	7	5.706	Stone ball
Tr5	203	7	5.707	Stone ball
Tr5	205	7	5.766	Stone polisher
Tr1	198	103	5.305	Bone scapula
Tr1	199	103	5.298	Bone
Tr1	200	103	5.244	Bone
Tr2	206	105	5.065	Bone
Tr2	205	105	5.099	Pot
Tr1	212	110	5.224	Bone
Tr1	211	110	5.146	Pot
Tr4	217	22	5.278	Flint
Tr5	215	7	5.726	Pot
Tr1	218	110	5.145	Pot
Tr2	227	100	5.221	Pot
Tr2	229	100	5.211	Bone
Tr2	228	100	5.21	Pot
Tr4	230	126	5.216	Bone
Tr4	219	126	5.268	Pot
Tr4	220	126	5.321	Pot
Trench 4	232	10	5.299	Ceramic
Trench 4	231	10	5.279	Ceramic
Tr4	238	131	5.268	Pot
Trench2	259	100	6.065	Polished tooth
Tr2	281	50	5.137	Iron object
Tr2	282	50	5.163	Stone
Tr4	267	131	5.274	Ceramic [rim sherd]
Tr4	268	131	5.269	Ceramic [rim sherd]
Tr4	260	131	5.152	Teeth
Tr4	265	131	5.158	Bone
Tr4	266	131	5.193	Bone
Tr1	280	103	5.22	Tooth and bone

Figure 6: Ortho-image plan of Whitegate, with small finds records overlaid.

occupation and construction which occurred over many centuries if not in some cases millennia – and the three dimensional information obtained from the laser scanning of the excavations at Keiss has proved to be crucial to its exegesis.

At Whitegate broch, laser scans were taken of the excavated areas at intervals deemed appropriate by the excavation directors, broadly representing the same intervals where a traditional hand-drawn plan was required (*Fig. 5*). The scans were collected at variable resolutions, averaging 3mm XY, and registered to the same georeferenced control as the terrain model and site-level surveys, thereby retaining the same spatial framework at the feature level as at the landscape scale.

One of the obvious advantages of scanning excavations – and the one that often appeals to field archaeologists – is the ability to produce rapid, accurate and detailed plans and sections of excavated features. This aspect of excavation recording has been used quite widely – experience of the same technique has been discussed by Shaw and Corns (English Heritage 2007, 40–1). Again, using orthotiffs and by exporting pointclouds to AutoCAD it was possible, very rapidly, to produce plans and sections in 2D for marking up by the excavators (*Fig. 6*), and these can be more effective than traditional plans, allowing elevation of 3D features to be displayed in a 2D representation (*Fig. 7*). This technique works well, although there are practical issues with the use of laser scanning to record excavated areas – e.g. keeping working areas clear for recording requires time management, while hardware issues such as the time involved in recording at sufficiently high resolution are likely to be reduced to irrelevance in future years, and newer laser scanners are already far faster and more versatile than the one used in this project.

However, the reduction of laser scanned data to two-dimensional plans and sections not only wastes archaeologically valuable 3D data, but also discards the information for which the technique was applied in the first place. The challenge in laser scanning for excavation recording is to retain the three-dimensionality of the laser scanned data, while simultaneously producing products that are

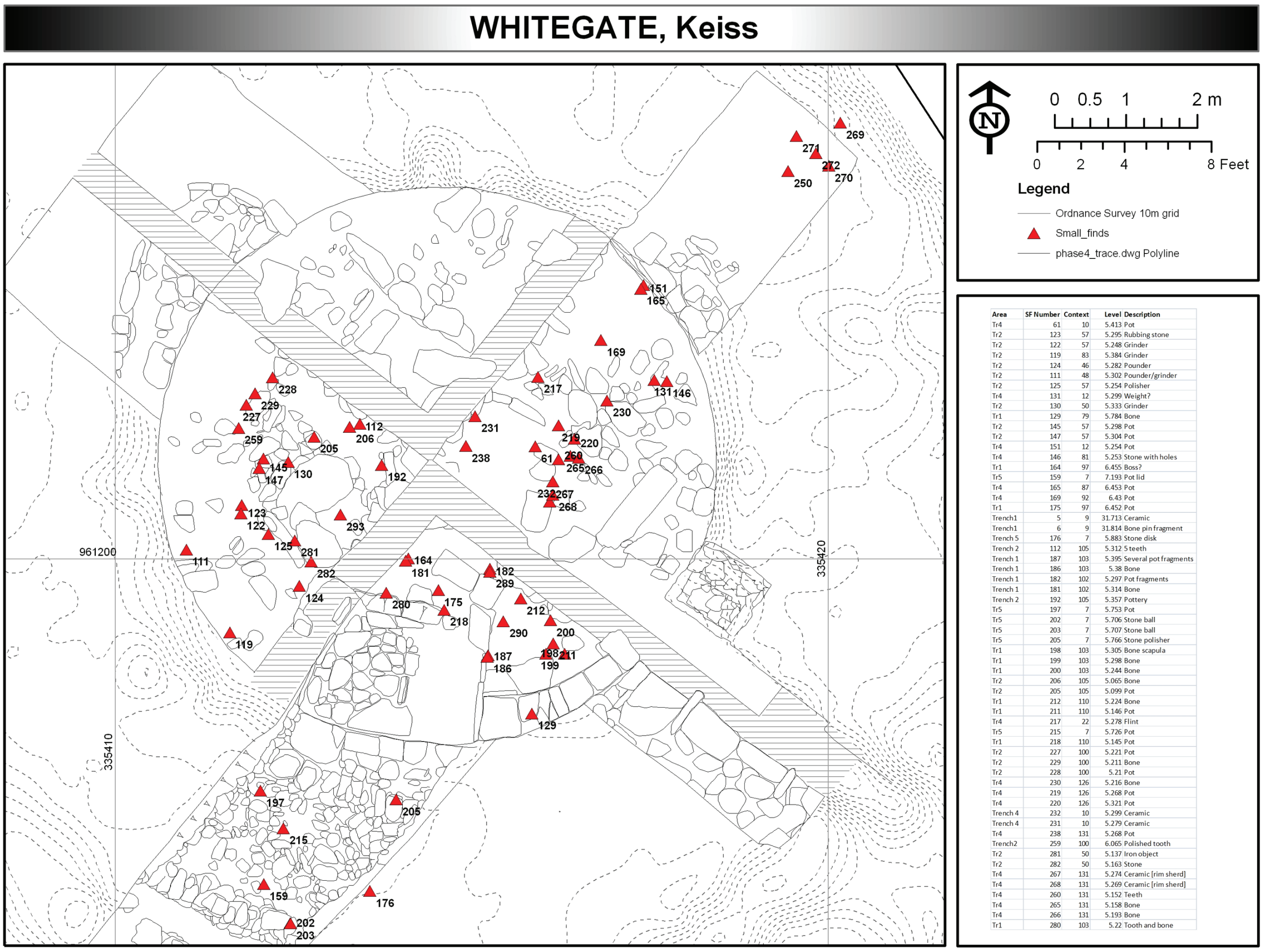


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Fig. 7. Extracted CAD plan, overlaid with small finds records in GIS.

compatible with archaeological interpretation and presentation in a feasible timeframe.

2.4. Integrating archaeological records: putting 'data' into 'space'

There are perhaps two principal routes when working towards merging laser scanned data and archaeological records. The ultimate aim being the storage and structuring of the collected archaeological information in a GIS environment, there are numerous hurdles involved in integrating the interpreted archaeological information relating to contexts, finds, samples and other information with the detailed – but interpretively 'mute' – spatial data.

The first of these routes, deriving geometrically modelled units representing deposit contexts and structural units using techniques such as fitted geometric primitives and voxels is perhaps the most straightforward path to the integration of 3D data to a GIS: most GIS will handle a three dimensional geometric vector model, allowing it to be assigned attribute data pertaining to context and other interpreted archaeological information. However, while this method has been successfully applied to large excavations (Doneus *et al.* 2003, 454–5; Losier *et al.* 2006) there are distinct drawbacks with this technique when applied to sites like those in Caithness. Geometric modelling is time consuming, and with the complexity of structural debris on a broch excavation the geometric data would either be too complex to be manageable or too simplified to be a good record of the deposit. Geometric modelling of deposits may only be easily used on simple negative features cut into soil deposits; it is possible that this is an issue that technological development will, in time, resolve, but for the moment representative geometric modelling of complex structural deposits seems unfeasible for anything other than the smallest excavation.

The second route, and the one taken here, is to work with the datasets in separate environments, but retaining links from one to the other. This allows direct manipulation of pointcloud data and small find, context and sample data was recorded as routine during the excavation using a total station running Strata's Penmap for Windows (for simpler example of this approach see Burgess *et al.* 1996). This was restructured into a geodatabase and incorporated with the other surveyed data in ArcGIS, allowing a traditional 2D intra-site GIS project to be constructed; this GIS provides the interrogable environment for the analysis of the archaeological information. The non-contiguous 3D laser scan data, registered to the same coordinate control as the other surveys was exported to the third party application Pointools and integrated with the finds data in 3D. Individual structural features were flagged in the cloud with descriptive notes incorporating context numbers and interpretation, while the small find data can be displayed by flagging with notes during the import process (*Fig. 8*). As a result, interrogation of the archaeological data can be carried out within a GIS environment, while visualisation and interrogation of the physical attributes of the data can be undertaken within a 3D environment (*Fig. 9*).

2.5. An integrated record as a tool for interpretation: discussion

This procedure provides a good methodology for the integration of detailed three dimensional spatial data with archaeological records deriving from an excavation: the results from this work have proven to be a useful tool for the interpretation of the site for the directors of the excavation, and the model of data structuring developed as part of this work allows the analytical functionality of GIS to be accessed in conjunction with the detailed spatial record provided by laser scan data (*Fig. 10*). However, while data linking allows a conceptual integration of the archaeological data collected, there are still significant hurdles to be overcome, and the full integration of all of the data in a way that allows for analytical functionality with a 3D environment

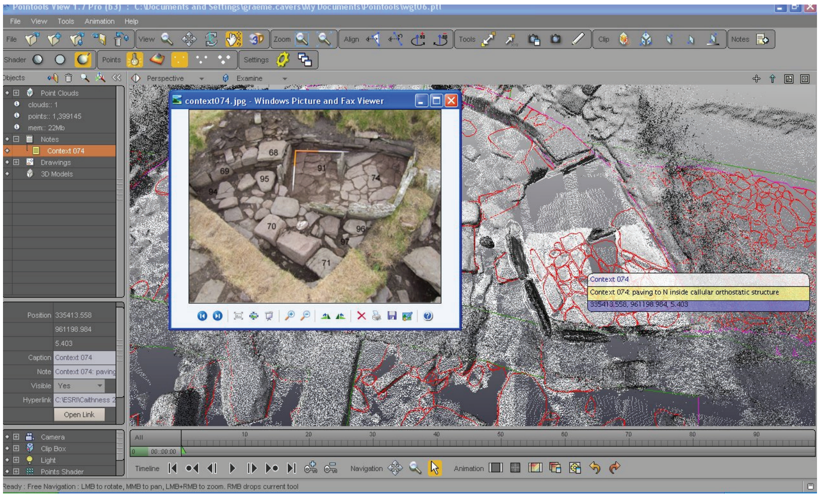

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Fig. 8. Point clouds, extracted CAD drawings and narrative photography integrated using hyperlinks in Pointools.

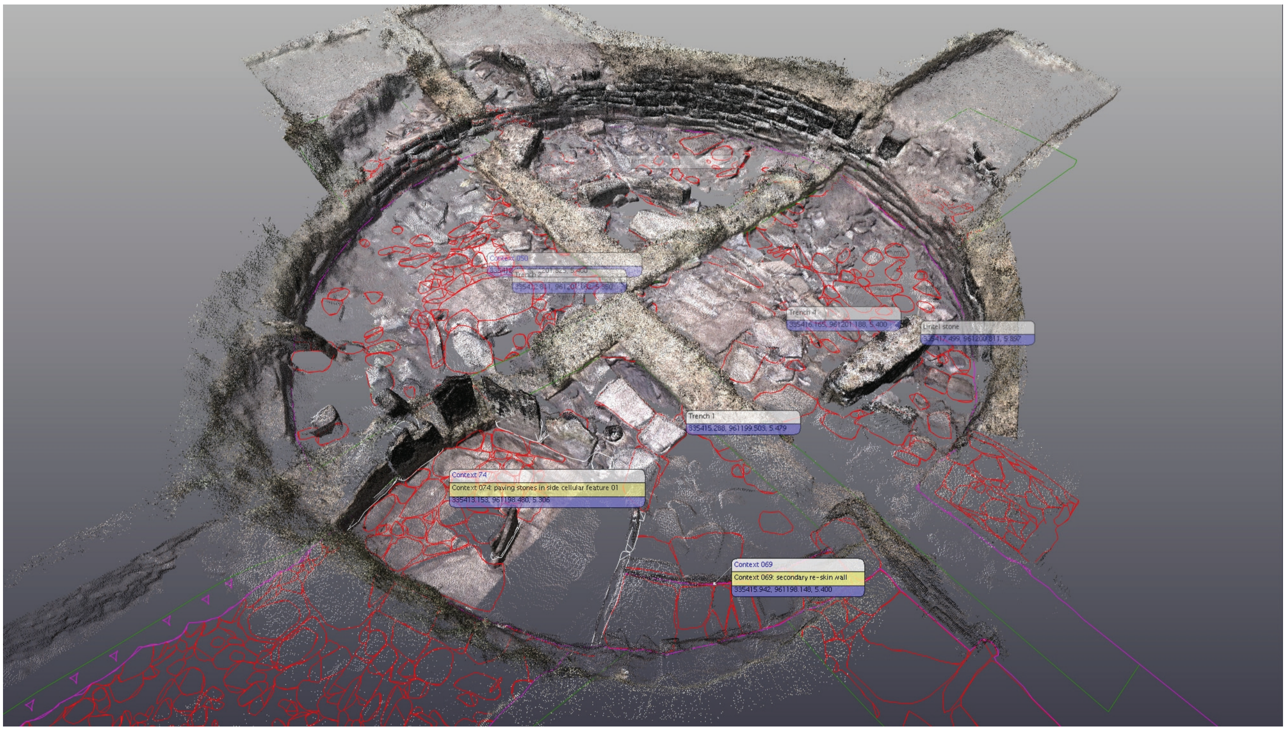

Fig. 9. Features flagged in 3D using Pointools.

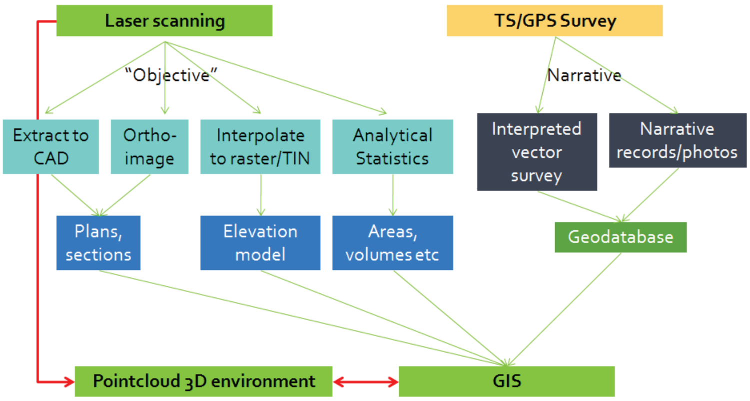

Fig. 10. Workflow for integrating archaeological records and 3D survey.

is still a target that has yet to be achieved. Pointcloud functionality within a GIS environment does exist, provided by LiDAR extensions like LP360 for ArcGIS, but like the methods described in this paper the 3D and GIS records are dealt with separately, with links between datasets providing the bridge between analysis and 3D information.

The recording of space and landscape is fundamental to the practice of archaeology and over the past two decades there have been significant advances in ways of thinking about space and landscape (in social archaeology) and the methods of recording them (using digital technology). Our archaeological survey work in Caithness has underlined to us that we are at a critical point in terms of theory and practice in archaeological survey. It is certain that the application of digital technologies such as laser scanning and GPS have enabled us to record archaeological landscapes and excavations in Caithness in greater detail than that achievable using traditional methods. But what is the use of this detail? How does it enrich our understanding of the past?

The epistemological arguments of the iconoclastic critics of Clarke's 'New Archaeology' made much of the observation that what were then termed 'facts' were often interpretations and survey, in particular, was identified as an exercise in the recording of interpretation, not the creation of a factual record. The interpretative element was deemed to subsist in the choices made by the surveyor as to what was surveyed. Typically, for example, a break in slope might be surveyed as a set of discete points joined by a line and then labelled in relation to some specific feature, e.g. 'edge of platform'. Accepting this general premise, the admixture of interpretation with the 'factual' three-dimensional locations of specific points cannot underpin the post-modern trend towards a position that relegates all survey to 'mere' interpretation.

Laser scanning short-circuits this debate somewhat because the instruments used make no choices about the points recorded. The post-modern response would no doubt be that the selection of the placement of the instrument preserves the interpretational nature of the surveys thus produced. This is, perhaps, true in the sense that the surveyor distinguishes between 'monument' and 'non-monument', but it does not re-introduce ambiguous choice into the record of that which is actually surveyed. For the very first time, therefore, we have a value-free survey method of recording which can bring us closer to the European policy *desideratum* of preservation by record where preservation in fact is not possible (Valletta Convention).

The points produced by laser scanners are, in their raw state, themselves independent of interpretation and constitute a value-free record of the site or monument thus surveyed. However, if laser scanning is to make a significant contribution to archaeology, interpretation in terms of current archaeological fashion must be grafted back onto it, albeit without distorting the original record. Interestingly, this potentially moves the locus of interpretation away from the monument and, via cyberspace, to any other location. It also facilitates forms of interpretation that are not easily achieved on site, such as the 'dismantling' of the structures to reveal forms visible at earlier stages, etc.

The use of GIS in correlation with laser scan and GPS data during the Keiss surveys allowed other interpretive elements to be added as extra layers of information to the survey while the surveyor was in the field. In this way it may be possible to begin to record elements of the 'socially constituted' and 'meaningful' aspects of archaeological landscapes (Ashmore and Knapp 1999) which are usually confined to theoretical narratives. The annotation of views in the field and indeed afterwards, including the incorporation of photographic data, facilitates the overlaying of layers of social, ideological and symbolic interpretations of archaeological landscapes without the need to constrain or bias the original surveyed digital data-sets.

Frieman and Gillings (2007) have argued that no survey can represent the totality of a given space, and a survey cannot of course replicate the essence or first hand experience of a particular space. Ultimately every archaeological survey, even a collection of 'mute' points, is an 'interpretation' of a space, even if, as already noted, only at the level of distinguishing archaeological spaces from other spaces in a 'monument/non-monument' framework. Thus, digital surveys and reconstructions can never be considered 'total' records. By including narratives and viewpoints within surveys we facilitate recognition of our bias by current or future scholars. By distinguishing between objective laser scan points and subjective interpretation, we facilitate query of the record by third parties at a level of methodological and theoretical 'transparency' which is usually lacking from archaeological surveys. In this way we can begin to overcome some of the shortcomings of written documents and two dimensional plans and insert an element of first hand experience into the 'record' of a survey.

We stated at the beginning of this paper that we were keen to develop a way of recording archaeological data that was in some way 'repeatable' or at least was capable of being meaningfully re-interrogated. A central tenet of scientific method, usually missing from archaeological method, is that for something to be objective its existence can be confirmed by other scientists repeating the processes that brought it to light in the first instance. Excavation is an interpretative practice, albeit based on commonly shared principles, and through its destructive nature it is not 'repeatable' – however, by recording excavations digitally in three dimensions as they progress we can produce a more detailed record of how a site was excavated which is open to more rigorous re-interpretation than a paper record if not actual re-excavation (the digital record could not be excavated in a different way – this would require every single stone, artefact, shell and soil particle of deposits to be surveyed as separate entities). In conjunction with the usual excavation data (context descriptions, photos, plans, samples etc.) linked through an interrelation GIS to the spatial digital data we can create a more 'transparent' record of our archaeological excavations from which data can be more easily extracted and used by third parties.

A final point for consideration is the presentation and archive of the data deriving from projects of this kind. Deposition and archive of "traditional" GIS data is now relatively straightforward, but if we are to realise the aim of an archaeological record that can be fully re-interrogated, new media for the dissemination of this data needs to be developed, and there is currently no satisfactory way of depositing a complex multi-resolution survey in a single environment that might be accessible to third party users. These and other issues are among those that we aim to address as part of the ongoing work in Caithness and elsewhere, as we work towards the creation of fuller, more objective and more transparent archaeological records.

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