44. Three-Dimensional Recording and Hull Form Modelling of the Newport (Wales) Medieval Ship

Nigel Nayling and Toby Jones

Introduction

The Severn Estuary, located on the western seaboard of Britain, has produced a series of notable boat and ship finds over the last two decades including Bronze Age sewn - plank boats, the Romano-Celtic vessel from Barland's Farm, and medieval clinker built vessels (Bell et al. 2000; Nayling 1998; Nayling & Caseldine 1997; Nayling & McGrail 2004). The most substantial of these was the Newport medieval ship discovered in 2002 during development on the banks of the River Usk, a major tributary of the Severn Estuary. Some 25 m of this ship were exposed in the deep excavations required during the construction of a performing arts centre on the river frontage, a few hundred metres downstream from the location of remains of the medieval castle (Roberts 2004).

Discovery, in situ Recording and Recovery

The ship was found heeled over onto its starboard side with much of its port side having been removed in antiquity (Fig. 44.1). Up to 17 strakes survived on the port side and 35 on the starboard side. Relatively closely spaced framing and remains of the inner hull comprising keelson, stringers, riders and ceiling planks also survived. Within the vessel, displaced ships' timbers including knees, beams, deck timbers and rigging elements were also recovered. The ship was recorded *in situ* using a combination of traditional scale hand drawing and stereo photogrammetry before being dismantled in approximately reverse order of construction.

Dismantling: Quantity, Diversity and Condition

Recovered timbers comprised a beech keel and oak stempost both of which had been heavily damaged by modern piling, 373 cleft radial oak planks, 220 framing timbers, 26 stringers, 64 ceiling planks, a single keelson with 20 braces and four riders. Collapse and compression of the ship timbers, found lying below some 5 m of alluvium and modern fill, was most noticeable on the starboard side. Disturbance created by the insertion of sheet steel piling and concrete piles, as part of the modern construction process, had also caused significant disturbance, resulting in fragmentation and substantial damage to numerous timbers. A total of 861 articulated ship timbers were recovered as 1683 fragments. Hence the ship timber assemblage was both far greater in number and scale than anything previously encountered in the region, and also both distorted and fragmented even though surface condition and general preservation was good.

Recording Trials

The scale and condition of the timber assemblage were significant considerations when deciding on an appropriate recording strategy as part of the post-excavation documentation of the ship. Recording trials were held exploring the merits, costs and limitations of well-established techniques such as 1 to 1 non-contact tracing along with utilisation of recent developments including laser scanning, and digital recording using a combination of FaroArm hardware and Rhino digital graphical software. Non-contact tracing was superficially attractive requiring relatively low capital outlay. Conversely the need for significant subsequent processing of a potentially enormous archive of acetate tracings through scanning and the production of vector two-dimensional graphics made this approach less attractive. Laser scanning promised rapid recovery of detailed

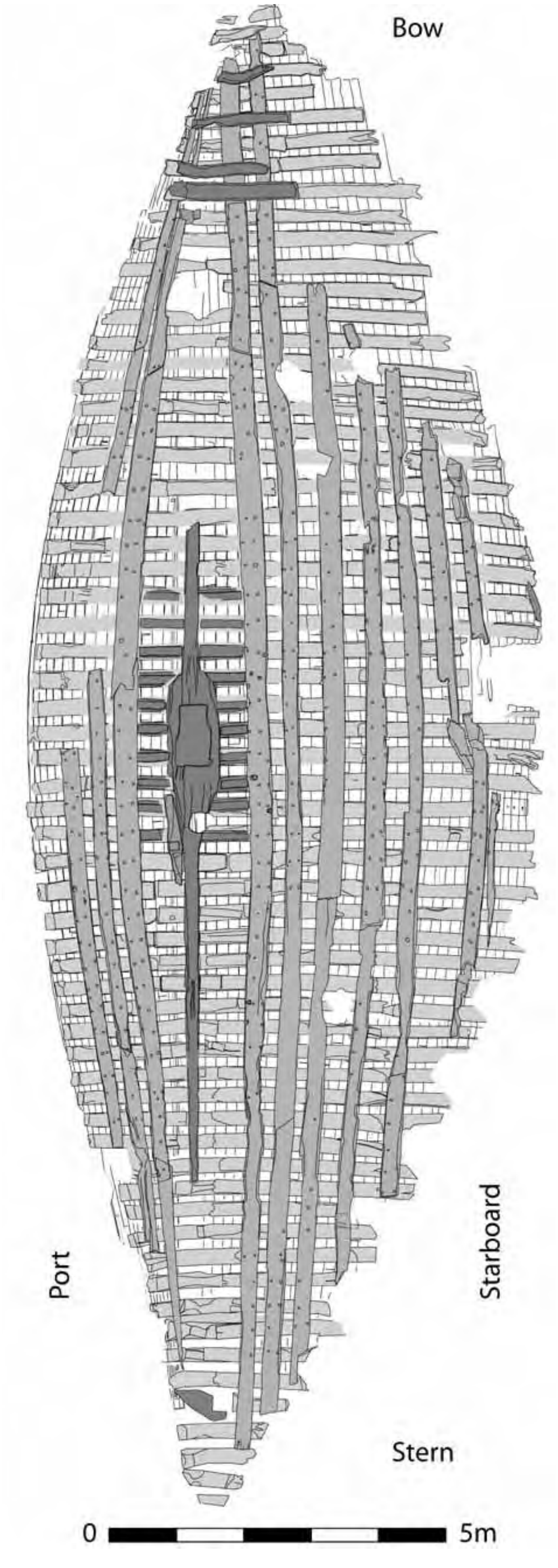

Fig. 44.1. Composite plan showing outer hull planks in outline, framing timbers in light grey, stringers in mid grey, and keelson, chocks, forward riders and aft pump in dark grey. After removal of ceiling planks (Drawing: Nigel Nayling).

Fig. 44.2. Recording a ship's timber using FaroArm and Rhino software (Photo: © Newport Museum and Heritage Service).

surface information from every timber, but again would require additional interpretation possibly through expert tracing onto the resultant point cloud of significant features. At the time, the size of the potential data generated by this technique was seen as potentially problematic and the need for an additional phase of interpretation made the rapidity of surface information capture less attractive. The third major approach assessed, the use of a CMM (co-ordinate measuring machine -FaroArm) linked to CAD like graphics software (Rhino), had been developed during documentation of the Hjortspring replica, and recording of the Kollerup cog (Hocker & Daly 2006).

The scale of the undertaking at Newport, the desirability of completing documentation relatively swiftly while the timbers remained in relatively good condition and the need to limit overhead costs such as building rental made the relatively high capital costs of FaroArm purchase and the associated investment in training acceptable. The potential quality of the three-dimensional recording, capturing both precise spatial information and selective interpretation through the use of an appropriately structured layer system led to this approach being favoured. Initially a single FaroArm was purchased and training of a small team initiated through support from the Viking Ship Museum in Roskilde. Following a successful bid to the Heritage Lottery Fund, a further three arms were purchased and additional workstations established so that an enlarged team could complete recording in a proposed two-year programme.

Documentation

The documentation of such a large timber assemblage required clearly defined procedures which could be communicated within a relatively large project team involved in cleaning, sampling, digital recording, and photography. At the outset a timber database was established to allow management of individual timbers including definition of their status within the documentation programme and a location within the many storage tanks required to hold the assemblage. As work progressed, entries for each timber were regularly updated ensuring effective tracking of the work programme, and the digitisation of selective information to assist in additional tasks such as prioritisation of timbers for dendrochronology sampling.

Individual timbers, or fragments thereof, were recorded using the system developed at the Viking Ship Museum with some refinements to address the particular needs of the Newport ship assemblage (Fig. 44.2). Conceptually, each timber was seen as a set of faces each recorded as a series of predetermined layers of graphical information. Thus, while three-dimensional line data is captured, the production of two-dimensional representations of each face of the timber, as has traditionally been published, is relatively straightforward. Layers employed to hold categorised information broadly comprised edges (including original, limit of, and damaged), wood grain and position of sapwood, clinker nails and roves, additional nails and nail angles, treenails and other wooden nails, wear, tool marks and intentional marks.

Digital recording was complemented by timber record sheets with attached printouts from the Rhino digital files. These record sheets were started during the cleaning of each timber so that any features of note identified at that stage could be communicated to whoever subsequently recorded the timber. With such a large assemblage of timbers and, at some stages, a large recording team, this proved a useful method of communicating information through the process of documentation. Following recording with the FaroArm and assessment of the resulting digital record, each timber was examined by the author (NN) and additional notes made, printouts of Rhino recording files assessed (and corrections requested where necessary), recommendations made for photography, and assessments of timber species, conversion, ring counts and dendrochronological dating potential made.

As recording progressed, the advantages of holding a digital graphical record for each timber became more apparent. Composite strake files, for instance, could be readily compiled and used to check consistency between timbers. Fragmented timbers could also be reconstructed in computer space even when the physical fragments could not be so readily rejoined. Highlighting fastening holes on the individual timbers or composites of adjoining timbers is also proving a useful analytical tool. Use of the digital record analytically certainly has the potential for further development.

Hypothetical Reconstruction

The role of hypothetical reconstruction within nautical archaeology is the subject of ongoing debate, with alternative interpretations of specific sites often fuelling discussion and publication (Crumlin-Pedersen 2006; Crumlin-Pedersen & McGrail 2006). A variety of approaches have been employed in the production of what have been called 'as found' reconstructions and torso diagrams of clinker built ships. The production of scale card models derived from one-to-one, non-contact traces of the outer hull planks is exemplified by reconstruction of the Skuldelev vessels (Crumlin-Pedersen 2002). Other approaches have included the use of one-to-one contact traces to produce a full scale reconstruction of the bow and surviving elements of the Magor Pill Wreck (Nayling 1998). Where a major output of documentation is a series of flat traces (either contact or non-contact), then the production of research models naturally proceeds through cutting out a flat medium whether that be card or timber. The generation of three-dimensional records, as seen in the use of a combination of FaroArm hardware and Rhino software, raises many questions about the use of this documentation in post-excavation analysis, research and presentation/dissemination. Three main methods of using digital records for the production of research models present themselves.

One might seek to 'flatten' the records for each plank and then cut a piece as a developed surface from a flat medium such as card, although the process of digital deformation may be hard to control realistically. Similar concerns could also pertain to an approach based purely on digital modelling through deformation of hull plank files solely within computer space. A 'third way' is the production of digital solids retaining the recorded shapes of individual

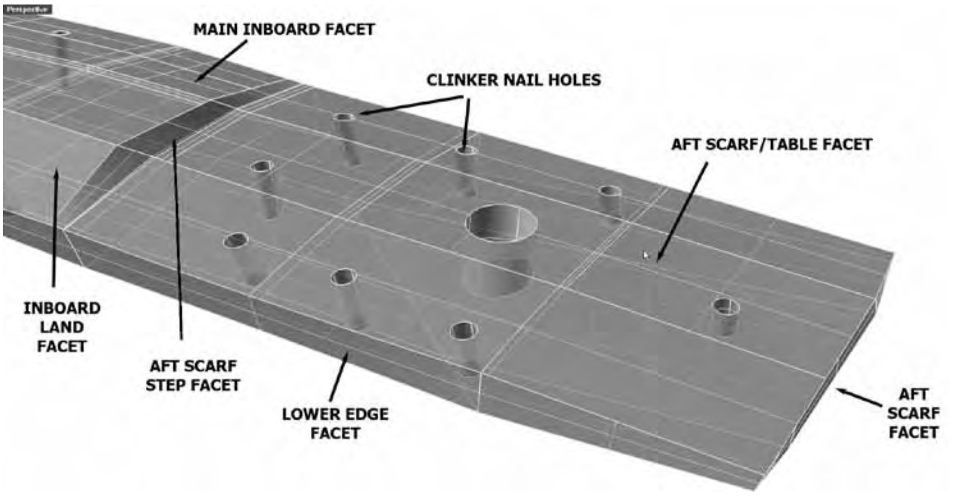

Fig. 44.3. Detail of model of aft scarf of an outer hull plank indicating modelled facets (parts of faces) and fastening holes (Drawing: Toby Jones).

hull planks along with the positions of any fasteners, which can then be manufactured at scale using an appropriately flexible material. Ideally, in the future, it may prove possible to attempt all three approaches on one or more vessels in order to assess the viability of such techniques and compare their results.

Research funding has been secured by the Newport Ship Project from the Arts and Humanities Research Council to undertake modelling of the Newport ship using this combination of the production of digital solids and their subsequent scale manufacture using rapid prototyping technology. This approach, both conceptually and practically, has benefited from discussion with colleagues who have joined together to form the Faro Rhino Archaeological User Group (FRAUG). A pilot study, based on the manufacture of a small number of hull planks, whilst indicating the viability of this method, also highlighted the need for systematic and transparent procedures during digital modelling, the need for calibration of the chosen manufacturing process (laser sintering), and careful consideration of the types of fasteners employed in model assembly so that appropriately sized fastening holes could be modelled and manufactured.

Digital Modelling Procedures

In the following section, details of the procedure being employed in the digital modelling of individual hull planks are briefly described.

Each hull plank is conceived as two faces (inboard and outboard) with each face comprising a set of adjoining surfaces or ‘facets’ which share some common edges. Hence, the inboard face would consist of the land, the main inboard face, and the step and table of the aft scarf (Fig. 44.3). The first stage in producing these surfaces is the drawing of simplified lines defining inboard edges (upper edge, lower edge, forward end, aft end, land, scarf upper step and scarf lower step) and outboard edges (upper edge, lower edge, forward end, aft end, land, scarf edge). The frequency of points or nodes along these lines is significantly reduced in comparison with those recorded with the FaroArm during documentation, and areas of damage are not replicated during the modelling of the edges. Additional topographic information is drawn from the cross sections recorded during documentation by producing simplified cross sections which intersect with the simplified edges previously produced.

Once all the simplified edges and cross sections have been drawn, these can then be used to produce the surfaces or ‘facets’ making up each face. Using the Rhino sweep 2 rails command, the two longest side edges of a facet are selected as the rails, and selected segments of cross sections between the rails used to produce the facet. This process is repeated until adjoining surfaces have been drawn for both inboard and outboard faces, as well as the upper and lower edges and forward and aft ends. It is important to note that all edges must be simplified before building any facets. All the digital surfaces are then selected and joined to form a single digital solid, technically known as a closed polysurface. Problems may occur at this stage when small differences in calculating the individual facets mean that adjacent surfaces are not perfectly joined (known as naked edges). These problems can be addressed through a combination of appropriate file settings and the corrective use of the join edge command.

Once the closed polysurface has been checked for integrity, it is converted into a mesh, a form of surface model based on small triangular facets which is similar in structure to the surface preferred for prototype manufacture. This surface model is again checked for its integrity, but also checked for conformity against the original record of the timber. The original record is then used to build simplified models of treenail and nail fastening holes as a series of pipes with set diameters to allow the use of standardised screw sizes during eventual model assembly. Subtraction of the modelled pipes from the model for the timber is a straightforward process. Using the same procedure (Boolean difference) the timber's unique identification number can also be in location.

With completion of modelling of the timber's form and fastenings, the model is reduced to required scale (in this case 1:10), and converted into the STL format required by the parts manufacturer. A range of rapid prototyping technologies were assessed during the pilot study in discussion with the Manufacturing Engineering Centre (MEC) at Cardiff University. Laser sintering offered a combination of fine surface detail capability with the use of an appropriately flexible, yet robust, material - polyamide 12 (nylon). Batches of the digital models are e-mailed to the manufacturer, with manufactured pieces usually being returned within five working days.

Model Assembly and Documentation

Model assembly commenced with the attachment of the garboard planks to the keel which had been modelled as several fragments, in part reflecting its fragmented state on site, but also recognising its deformed state and allowing planking to determine original keel form. Small metal screws designed to cut thread through thermoplastic were used to fasten the garboards to the keel, replicating the driving of round-headed spike nails into the original keel. Assembly proceeded rapidly where original timbers were in good condition, with a batch of perhaps 50 parts being added to the model on the same day as their arrival (Fig. 44.4).

Model documentation has so far depended largely on a combination of photography and laser scanning. The intention is to draw down a series of sections from successive laser scans to examine how the hull form changes through the process of assembly. At present a significant number of outer hull planks have been modelled (the most time-consuming aspect of this approach to modelling), and the modelling of framing timbers is well progressed.

Fig. 44.4. Perspective view of the laser sintered, 1:10 scale model of the Newport Ship. All of the hull planking and half of the framing have been added (Photo: © Newport Museum and Heritage Service).

The Future

The project aims to complete modelling of the ship's framing timbers, stringers, keelson and riders over the next two years. Disarticulated timbers which may have formed upper hull elements such as beams and standing knees will also be modelled. As the model grows, providing a dynamic display item for visitors to the ship centre, we will continue to document its development but also consider its potential use as an analytical tool for more detailed consideration of particular aspects of construction complementing examination of the detailed digital records for individual timbers. Output from the modelling will also be necessary in the development of detailed proposals for the eventual display of the conserved and reassembled timbers.

Fortunately, projects and institutions in a number of countries are either considering or actively using very similar processes of documentation, and in some cases modelling. The formation of a user's group for nautical archaeologists using FaroArms and Rhino software (FRAUG) has helped push forward developments and encouraged useful communication between colleagues. Critical assessment of the validity of the modelling approach taken here will possibly require further research including parallel trials of traditional physical modelling techniques, the usage of digital modelling and rapid prototyping outlined here, and potentially modelling which occurs purely within a digital environment (Ravn in this volume). Co-operation and co-ordination within this flourishing group will be mutually beneficial in considering further methodological development. How we work with three-dimensional digital documentation analytically, and how we use it for dissemination (whether that may be academic publication or wider interpretation) are key areas for consideration in building on the increasingly widespread uptake of digital recording in nautical archaeology. Consultation on the appropriateness of processes using digital data need also to be appraised by the wider archaeological community before equally widespread commitment to such approaches will develop.

Acknowledgements

A project of this scale would not have been possible without substantial support from a wide range of sponsors. Major funding bodies include Newport City Council, Cadw: Welsh Historic Monuments, the Welsh Assembly Government, the Heritage Lottery Fund and the Arts and Humanities Research Council. The Friends of the Newport Ship continue to provide enthusiastic support and assistance.

References

Bell, M., Caseldine, A., Neumann, H., Taylor, B. & Allen, J. R. L., 2000, *Prehistoric intertidal archaeology in the Welsh Severn Estuary*. Council for British Archaeology Research Report 120. York.

Crumlin-Pedersen, O. & Olsen O, (eds) 2002, *The Skuldelev Ships I. Topography, Archaeology, History, Conservation and Display*. Ships and Boats of the North, vol 4.1. Roskilde.

Crumlin-Pedersen, O., 2006, The Dover Boat - a Reconstruction Case-Study. *International Journal of Nautical Archaeology* 35.1: 58-71.

Crumlin-Pedersen, O., & McGrail, S., 2006, Some Principles for the Reconstruction of Ancient *Boat Structures. International Journal of Nautical Archaeology* 35.1: 53-57.

Hocker, F. & Daly, A., 2006, Early cogs, Jutland boatbuilders, and the connection between East and West before AD 1250. In L. Blue, F. Hocker, & A. Englert (eds), *Connected by the Sea. Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003,* 187-194. Oxford.

Nayling, N., 1998, *The Magor Pill Medieval Wreck*. Council for British Archaeology Research Report 120. York.

Nayling, N., & Caseldine, A., 1997, *Excavations at Caldicot, Gwent : Bronze Age paleochannels in the Lower Nedern Valley*. Council for British Archaeology Research Report 108. York.

Nayling, N., & McGrail, S., 2004, *The Barland's Farm Romano-Celtic boat*. Council for British Archaeology Research Report 138. York.

Roberts, O. T. P., 2004. Llong Casnewydd: the Newport Ship-a Personal View. *International Journal of Nautical Archaeology* 33.1: 158-163.

BETWEEN CONTINENTS

Proceedings of the Twelfth Symposium on Boat and Ship Archaeology
Istanbul 2009

Edited by
Nergis Günsenin

ISBSA 12

Sponsored and Hosted by the
Istanbul Research Institute of the Suna and İnan Kıraç Foundation

Under the auspices of the Underwater Technology Program at Istanbul University's
Vocational School of Technical Sciences in partnership with
the Faculty of Letters, Department of Restoration and Conservation of Artefacts

OFFPRINT

ege
YAYINLARI

BETWEEN CONTINENTS

Proceedings of the Twelfth Symposium on Boat and Ship Archaeology
Istanbul 2009

ISBSA 12

Edited by
Nergis Günsenin

ISBN No: 978-605-4701-02-5

Published by

Ege Yayınları

Publisher Certificate No: 14641

Cover illustration

Antoine Ignace Melling, *A Picturesque Voyage to Constantinople and the Shores of the Bosphorus*,
“View of the Naval Shipyards of Constantinople”

Cover design

Aydın Tibet

With special thanks to

SUNA AND İNAN
KIRAÇ FOUNDATION

Printed by

Paragraf Basım Sanayi A.Ş.
Yüzyıl Mah. Matbaacılar Sit.
2. Cad. No: 202/A Bağcılar İstanbul
Tel: 0212 629 06 07 Fax: 0212 629 03 85
Certificate No: 18469

Production and Distribution

Zero Prodüksiyon
Kitap-Yayın-Dağıtım San. Ltd. Şti.

Abdullah Sokak, No: 17, Taksim, 34433 İstanbul/Türkiye
Tel: +90 (212) 244 7521 Fax: +90 (212) 244 3209
E.mail: info@zerobooksonline.com

www.zerobooksonline.com

www.egeyayinlari.com