EGM502 Seafloor Mapping

Lecture 22: Archaeological Applications
Lecture 23: Archaeological Case Studies
Lecture Structure

1. Introduction to Maritime Archaeology and Geoarchaeology
   • Definitions
   • Historical background

2. Shipwrecks:
   • Detection and imaging
   • Site Formation Processes
   • Case study

3. Submerged landscapes:
   • Definition
   • Application of marine geophysics
   • Case study
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Maritime Archaeology

Maritime archaeology is the study of vessels, cargoes and human remains that lie hidden beneath the waters of our oceans, lakes and rivers.

Geo-Archaeology

“the contribution of the earth sciences...to the interpretation of archaeological contexts” (Gladfelter, 1977)

• Locating sites
• Site formation processes
• Reconstruction of past landscapes
Maritime archaeology

Submerged landscapes

Shipwrecks
Maritime geoarchaeology

Submerged landscapes

Shipwrecks

Geophysical prospection
Site formation processes
Landscape reconstruction

Geophysical prospection
Site formation processes
Diving on sunken ships has happened throughout history. Alexander the Great is reputed to have gone down in a diving bell (325BC), while Roman free divers apparently salvaged cargo from a wreck 20m deep off the south of France.

http://library.thinkquest.org/28170/221.html
The aqualung opened the underwater world to diving adventurers like Hans Hass and Jacques Cousteau in the 1940s. Although many ancient wrecks were found, little thought was given to their archaeological significance.
It was not until 1960 that a young archaeologist, George Bass, teamed up with explorer Peter Throckmorton to investigate a Bronze Age shipwreck at Cape Gelidonya in Turkey. Bass learned to dive and showed that archaeology could be done underwater to the same standards as on land.
- (statistical) analysis of the environment and site preservation
- discusses processes such as currents, waves, fetch, slope of seabed, topography and sediments

‘maritime archaeology is the scientific study, through the surviving material evidence, of all aspects of seafaring: ships, boats, and their equipment; cargoes, catches, or passengers carried on them, and the economic systems within which they were operating; their officers and crew, especially utensils and other possessions reflecting their specialized lifestyle’ (Muckelroy 1978, p. 6).

- Between 1974 – 1980: seven journal articles and 2 books
From the 1990s to present, increasing amounts of maritime geoarchaeology are conducted by commercial archaeological companies as part of the Environmental Impact Assessment process for offshore development (e.g. Wind parks, cables, pipelines)
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Shipwreck detection and imaging

Most work in the 1960-80s relied heavily on diving. This however had disadvantages:

1) Slow
2) Expensive
3) Problems with visibility
4) Restrictive time under water
5) Restrictive depth
6) Dangerous
7) Difficult to see the entire site

Logboat: Lough Neagh. ~50cm visibility (photo: R. McNeary)
Shipwreck detection and imaging

The use of marine geophysical techniques allows archaeologists to overcome some of these disadvantages

1) Slow

2) Expensive

3) Problems with visibility

4) Restrictive time under water

5) Restrictive depth

6) Dangerous

7) Difficult to see the entire site

SS *Lugano* off Rathlin Island
The primary systems for marine geoarchaeology are:
Sidescan sonar

Towed system

Hull-mounted

(Klein Associates Inc.)
Sidescan sonar examples
- Range settings
- Frequency settings
Swath bathymetry

Sidescan sonar was the traditional workhorse of marine geoarchaeology, but swath is becoming increasingly common especially in commercial archaeology.

Shipwrecks: Belfast Lough
(data from Royal Navy & UKHO)
HMS Royal Oak: torpedoed in Scapa Flow 1939.

SS Richard Montgomery: wrecked 1944

High-resolution swath survey combined with specialist visualization software
Arklow Bank wreck: discovered 2003 as part of pre-installation surveys for an offshore wind park

Sidescan draped over swath

Swath
Sidescan collects only backscatter, multibeam (swath) collects both bathymetry and backscatter.
Positions given in Eastings/ Northings UTM Zone 30 (WGS84)

Wreck Buoy
sinker
606286.6
5618609.2

Yacht Mooring Anchor
606264.4
5618569.4

Wreck Area

Block 2
606287.9
5618544.5

Block 1
606266.1
5618533.7
Magnetometer
- Detects fluctuations in the Earth’s magnetic field caused by metallic objects

Magnetometer survey of the Arklow Bank Wreck

(www.whoi.edu)
Sub-bottom profiler
- Buried objects
- Penetration and resolution vary with system used
- Limitation compared to swath and sidescan: slices rather than swaths → easier to miss targets
- Detect either wreck itself or scour features associated with it
Buried wreck site (Duncannon, Co. Waterford) (Quinn 2006)

Buried scour pit (Mary Rose, Portsmouth) (Quinn et al. 1997)
Tightly spaced survey lines (10m) allowed creation of a pseudo-3D model.

Seismic amplitudes draped over bathymetry. High amplitude = scour features.

Mary Rose (Portsmouth) (Quinn et al. 1997; Quinn 2006)
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Why look at site formation processes?

- Determine how a site has formed (are we missing anything from the archaeological record?)
- Determine how a site will continue to evolve (will preservation improve/degrade over time?)

\[
\frac{dD}{dt} = \frac{dP}{dt} \pm \frac{dC}{dt} \pm \frac{dB}{dt}
\]

where \( \frac{dD}{dt} = \) rate of **wreck disintegration**;
\( \frac{dP}{dt} = \) rate of **physical** disintegration;
\( \frac{dC}{dt} = \) rate of **chemical** disintegration;
\( \frac{dB}{dt} = \) rate of **biological** disintegration.
Site formation – physical processes

**Hydraulic forces**: direct impact on the archaeological material by waves, tides, storms, currents

**Abrasion**: physical abrasion of material by moving sediment (‘sandblasting’)

**Pressure**: increases with depth

**Waterlogging**: Water absorption by organic artefacts may weaken their structure

**Scour**: Archaeological material disrupts the local hydrodynamic regime leading to localized patterns of sedimentation and erosion

Ship timbers partly buried in sand (White Rocks, Portrush)
Site formation – biological processes

**Benthic fauna** (e.g. lobster and crabs)
- Mechanical Damage (abrasion)
- Creation of aerobic pockets
- Mixing of stratigraphic relationships (benthic bioturbation)

**Woodborers** (e.g. teredo)
- Degradation of wooden artefacts

**Microorganisms**
- Mechanically break down artefacts (e.g. woodboring)
- Chemically break down artefacts (e.g. oxidation)
Site formation – chemical processes

Direct reaction

• Corrosion of metal artefacts by sea water

Biochemical reactions

• Acidic conditions may degrade organic material
• Physiochemical reactions of microorganisms (e.g. oxidizing bacteria)
Rathlin anchor find: before concretion removal
Rathlin anchor find: after concretion removal (NOT THE RIGHT WAY TO DO THIS!)
Site Formation Process model (Ward et al., 1999)
Overall, the open system is characterized by:
1. Negative dynamic equilibrium;
2. Persistence of short-term variation around overall negative system state.
Site formation example: physical processes

Comparison: *Stirling Castle* (1703; Goodwin Sands). Surveyed: 2002 to 2005

2002 (note the relatively smooth seafloor surrounding the wreck site)

2005 (note the large sandwaves)

Image courtesy of Richard Bates
Profile through sandwave showing topographic change around *Stirling Castle* wreck site, 2002 to 2005

Difference map of seafloor bathymetry between 2002 and 2006. Note the significant erosion in the lee of the site. Also note the large, asymmetric sandwaves in the 2005 data that suggest sand movement from left to right (southwest to northeast) across the site.
Site formation example: scour processes
Different types of flow lead to different types of scour. This affects:

- Which parts of the wreck get buried/exposed
- Artefact distributions
SS Stypie, 1827 (?), Lough Foyle
SS Tiberia, 1918, Belfast Lough
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Previous examples show that marine geophysics is well suited to:

- Detecting exposed wrecks
- Monitoring site formation (esp. physical processes on exposed wrecks)

Can we take it even further?
Case study: the *Grace Dieu*

- 1418 - Henry V’s flagship (Southampton)

- Largest ship in England up to that time (and for another 200 years!!!!)

- Warship … but never saw action

- 1420 - in reserve in the Hamble River functioning as technological marvel to impress foreign dignitaries

- 1439 - struck by lightning: burnt down to waterline, sunk at her berth in Hamble River

Henry V (1387-1422; r. 1413-1422)
Site location
Site discovery

• 1875 – ship uncovered and partially destroyed. Thought to be a Viking ship

1990s: survey of timbers poking out of the mud at very low tide, excavation conditions v. difficult (muddy, up to 5m tidal range)

2003-06: new study – determine the dimensions and shape of the buried wreck with marine geophysics (Plets et al. 2008; 2009)
2D vs 3D Chirp system

2D system: DGPS (metric accuracy only)
2D vs 3D Chirp system

3D system: RTK-GPS (centimetric accuracy)
Deployment - problems

⇒ Wake bubble cloud of vessel’s propellers

⇒ Acoustic blanking in the water column
Deployment – solution

“non-motorised deployment” : divers
Deployment – solution

“non-motorised deployment” : divers
2D & 3D survey
2D results

Max. line-line spacing: 2.5 m

Average shot-shot spacing: 4.0 cm

39 lines in total

1250 m of acoustic data

Covering 1800 m²
3D results

Data binning:
0.125m x 0.125m

Data Volume:
50m x 50m
Seismic section (vertical) – 2D

Direct arrival

Anomaly (~11.5m)

River Bed

Geology

Acoustic blanking
Seismic section (vertical) – 3D

Anomaly (~12m)

River Bed

Geology

Acoustic blanking

TWT (ms)
3D data: amplitude map (horizontal slice). Depth: riverbed
3D data: amplitude map (horizontal slice). Depth: 0.1ms
3D data: amplitude map (horizontal slice). Depth: 0.2ms
3D data: amplitude map (horizontal slice). Depth: 0.3ms
3D data: amplitude map (horizontal slice). Depth: 0.4ms
3D data: amplitude map (horizontal slice). Depth: 0.5ms
3D data: amplitude map (horizontal slice). Depth: 0.6ms
3D data: amplitude map (horizontal slice). Depth: 0.7ms
3D data: amplitude map (horizontal slice). Depth: 0.8ms
3D data: amplitude map (horizontal slice). Depth: 0.9ms
3D data: amplitude map (horizontal slice). Depth: 1ms
3D data: amplitude map (horizontal slice). Depth: 1.1ms
3D data: amplitude map (horizontal slice). Depth: 1.2ms
3D data: amplitude map (horizontal slice). Depth: 1.3ms
3D data: amplitude map (horizontal slice). Depth: 1.4ms
3D data: amplitude map (horizontal slice). Depth: 1.5ms
3D data: amplitude map (horizontal slice). Depth: 1.6ms
3D data: amplitude map (horizontal slice). Depth: 1.7ms
3D data: amplitude map (horizontal slice). Depth: 1.8ms
3D data: amplitude map (horizontal slice). Depth: 1.9ms
3D data: amplitude map (horizontal slice). Depth: 2 ms
Final outcome: vessel reconstruction

Basic reconstruction (based only on seismic data)
Final outcome: vessel reconstruction

Hypothetical reconstruction (based on combining seismic data with shipbuilding software)

- Each survey lasted approx. 2 days followed by several months of processing

- Exposing the wreck by excavation would have taken weeks or months followed by months of data analysis and years of conservation if the exposed wood was removed
Key concepts (shipwrecks)

• Conventional marine geophysical techniques are now an essential part of maritime geo-archaeology

• Main purpose is to detect and image wrecks

• Main systems used are sidescan, swath bathymetry, magnetometer and to a lesser extent, sub-bottom profiler

• Repeat surveys can be used to determine change over time (site formation processes)

• Best suited to exposed/partly buried wrecks

• The challenge is to develop non-intrusive methods of investigating fully buried wrecks.
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**Definition**

**What are submerged landscapes?**

Areas of land that have been submerged by sea-level rise and which are preserved on the continental shelf.

Submerged forest, Wales

Intertidal peat, England
Climate Change – the last 5 million years

Ocean sediment core data from Lisiecki & Raymo (2005)
Climate and Sea-Level Change – the last 500,000 years

Black = glacio-eustatic sea-level
Grey = $^{18}$O

$^{18}$O data from Lisiecki & Raymo (2005)
Climate and Sea-Level Change – isostatic modification to global sea-level
Example: palaeo-geography of the British Isles at intervals over the last 500,000 years
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What kinds of archaeological evidence are we looking for?

- Palaeolithic/Mesolithic (Stone Age) on land
What kinds of archaeological evidence are we looking for?
- Palaeolithic/Mesolithic (Stone Age) underwater

Mammoth remains from the North Sea: Mol (2007)
What kinds of archaeological evidence are we looking for?

- Palaeolithic/Mesolithic (Stone Age) underwater

Handaxes from South Africa: 300,000 to 1,200,000 years old

Stone tools from Denmark: 8000 years old

Handaxe from the North Sea: 70 to 130,000 years old

What kinds of archaeological evidence are we looking for?

- Palaeolithic/Mesolithic (Stone Age) underwater
What kinds of archaeological evidence are we looking for?

- Palaeolithic/Mesolithic (Stone Age) underwater

Human skull – Tybrind Vig, Denmark: Andersen (1985)
What kinds of archaeological evidence are we looking for?

- Palaeolithic/Mesolithic (Stone Age) underwater

Wooden fish trap, Havang (Sweden): 9000 years old

Wooden decorated paddle Hjarno (Denmark): 5-6000 years old
What kinds of archaeological evidence are we looking for?

Pre-pottery Neolithic well, Israel

(Galili et al. 1993)
What kinds of archaeological evidence are we looking for?

Palaeo (old) landsurfaces

Wood embedded in submerged peat (Co. Donegal)

Hazelnuts embedded in submerged peat (Co. Donegal)
Can we detect scatters of bones and stone tools with marine geophysical techniques?

Quinn et al. 2005. Control experiment on backscatter responses, Belfast Lough
Can we detect scatters of bones and stone tools with marine geophysical techniques?

“a very wide range of submerged organic and inorganic materials can be imaged using side-scan sonar. However, individual targets may be difficult (or impossible) to resolve when they are out of context. It is apparent that many of the materials deployed could not be interpreted on the basis of their backscatter response alone” (Quinn et al. 2005: 1263)
What can marine geophysics contribute to submerged archaeological landscape research?

- Locate past landscape features on, or buried within, the seabed
- Reconstruct what the past landscape looked like and how it changed over time
  - Predictive modelling of past human site preferences
  - Identification of areas of preservation
  - Identification of areas of high archaeological potential
  - Human responses to environmental change
Ground-truthing geophysical data
Non-intrusive observations of seabed sediment and geomorphology
Ground-truthing geophysical data

Intrusive sediment sampling – recover material for dating, sediment samples to confirm origin of seabed and sub-seabed deposits
Ground-truthing geophysical data

Intrusive sediment sampling – recover material for dating, sediment samples to confirm origin of seabed and sub-seabed deposits
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   - Case study: North Coast of Ireland
Background

Research Question:
What evidence is there for past sea-level change, submerged palaeo-landscapes and associated archaeological evidence off the north coast of Ireland?

Sea-level change:

Modelled sea-level curves from GIA model (Brooks et al. 2008)
Method:

1. Large scale landscape reconstruction using multibeam bathymetry and seisms where possible

2. Identify preserved landscape features

3. Assess preservation conditions using multibeam and seismic

4. Determine archaeological potential

5. Investigate high potential area with additional geophysical survey or ground-truthing
Method:

1. Large scale landscape reconstruction using multibeam bathymetry and seismics where possible

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Multibeam bathymetry – the JIBS survey
Multibeam based reconstruction – -30m lowstand (c. 13,500 cal BP)
Multibeam and seismic-based reconstruction – (c. 12,000 cal BP)
Method:

1. Large scale landscape reconstruction using multibeam bathymetry and seisms where possible

2. Identify preserved landscape features

3. Assess preservation conditions using multibeam and seismic

4. Determine archaeological potential

5. Investigate high potential area with additional geophysical survey or ground-truthing
Identification of landscape features: possible submerged cliffs/platforms, Ballycastle Bay

High-resolution bathymetric DEM (JIBS) combined with terrestrial DEM (LPS NI)
Wave-cut platforms – Seaport Lodge, Portballintrae
Identification of landscape features: possible submerged peat, Portrush West Bay

JIBS backscatter data with sub-bottom profile tracklines
Portrush West Bay: intertidal/submerged peat

Dated to ~7000-8000 cal BP
Identification of landscape features: possible submerged peat, Portrush West Bay.

JIBS bathymetry (depth) data with sub-bottom profile tracklines.
Identification of landscape features: possible submerged peat, Portrush West Bay

Example subbottom profiles with core positions targeting the first buried layer
(data courtesy of METOC Plc & Titan Environmental Surveys Ltd)
Identification of landscape features: possible submerged peat, Portrush West Bay

Example subbottom profiles with core positions targeting the first buried layer
(data courtesy of METOC Plc & Titan Environmental Surveys Ltd)
Method:

1. Large scale landscape reconstruction using multibeam bathymetry and seismics where possible

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4. Determine archaeological potential

5. Investigate high potential area with additional geophysical survey or ground-truthing
Archaeological preservation potential example: Rathlin Island

High potential bays and estuaries vs. low potential rock cliffs and platforms

Combined terrestrial elevation (from Land & Property Services, Northern Ireland) and marine bathymetric (from JIBS project) Digital Elevation Models

Deep water (not exposed at lowstand), steep cliffs, exposed rocky seabed. Low potential

Shallow bay (exposed at lowstand), sandy seabed, seismic profiles show buried layers. Higher potential
**Method:**

1. Large scale landscape reconstruction using multibeam bathymetry and seismics where possible

2. Identify preserved landscape features

3. Assess preservation conditions using multibeam and seismic

4. **Determine archaeological potential**

5. Investigate high potential area with additional geophysical survey or ground-truthing
High archaeological potential example – Bann Estuary

Example based on multibeam bathymetry only, future work will use combined bathymetry and ground-truthed sub-bottom profiles
Overall archaeological potential

Palaeo-landscape reconstruction
(human site preference)

Preservation conditions
(burial not erosion)

Example based on multibeam bathymetry only, future work will use combined bathymetry and ground-truthed sub-bottom profiles
Method:

1. Large scale landscape reconstruction using multibeam bathymetry and seismics where possible

2. Identify preserved landscape features

3. Assess preservation conditions using multibeam and seismic

4. Determine archaeological potential

5. Investigate high potential area with additional geophysical survey or ground-truthing
   - Ballycastle west possible shoreline
   - Portrush West Bay possible peat
   - Greencastle possible submerged archaeological site
Ground-truth locations

1. Ballycastle-Ballintoy
2. Portrush West Bay
3. Greencastle

Palaeo-landscape reconstruction

Preservation conditions
Identification of landscape features: possible submerged cliffs/platforms, Ballycastle Bay

High-resolution bathymetric DEM (JIBS) combined with terrestrial DEM (LPS NI)
Ballycastle-Ballintoy: submerged shoreline
- Lithology = limestone/chalk; not basalt
- Notches visible at most sample sites, cut into rock by 6-80cm deep
Lithology = limestone/chalk; not basalt

Notches visible at most sample sites, cut into rock by 6-80cm deep

Ballycastle-Ballintoy: submerged shoreline

(Photo: NFSD)
Lithology = limestone/chalk; not basalt

Notches visible at most sample sites, cut into rock by 6-80cm deep
Portrush West Bay intertidal/submerged peat

Coring positions chosen from seismic data
Portrush West Bay intertidal/submerged peat

- PRWC_9_2: 2m water depth
- PRW_8_1: 3m water depth

- 79cm sand
- 83cm sand
- 10cm peat

8900 - 9250 cal BP
Potential extent and depth of submerged peat interpolated from seismic profiles
Greencastle (Eleven Ballyboes): approximate palaeo-landscape reconstruction

High potential area:
- Former fluvial/estuarine landscape
- Extant intertidal lithic collections
Greencastle: intertidal/submerged Mesolithic site

- c. 1500 finds
- c. 50 finds

Western Bay

Eastern Bay
Greencastle: intertidal lithics
Greencastle: 2011-2013 field seasons
Greencastle: Western bay results

- 10 test pits (5m and 2.5m spacing)
- 75 excavated lithic finds
- 33 surface lithic finds
- Reworked silty gravel deposit?
Greencastle: Western bay representative underwater finds
Greencastle: Eastern bay results

- 3 excavated test pits (5m spacing)
- 4 block-lifted test pits
- Buried and eroded peat & organic deposits
- No lithic finds to date
Greencastle: Eastern bay baseline profile

Radiocarbon dated to c. 8700-9400 BP
Greencastle: Eastern bay submerged peat (eroded surface)

Peat edge

Tree trunk/branch (*Salix*)

Pine needles?

Hazelnuts
Key concepts (submerged landscapes)

- Conventional marine geophysical techniques are now an essential part of maritime geo-archaeology
- Key purpose is to collect data for palaeo-landscape reconstructions
- Key purpose is to assess preservation conditions
- Key purpose is to identify actual palaeo-landscape features
- Main systems used are sub-bottom profiler and swath bathymetry
- Ground-truthing is essential
- The challenge is to go from reconstructed landscape to finding actual archaeological material