STRONG MAR

Marine geological data: from shallow seas to deep oceans

Heather Stewart

17th November 2016

Historical perspective and modern techniques


BGS, 1889


Circa 1900

Geological Survey of Scotland, NW Highlands

Offshore exploration

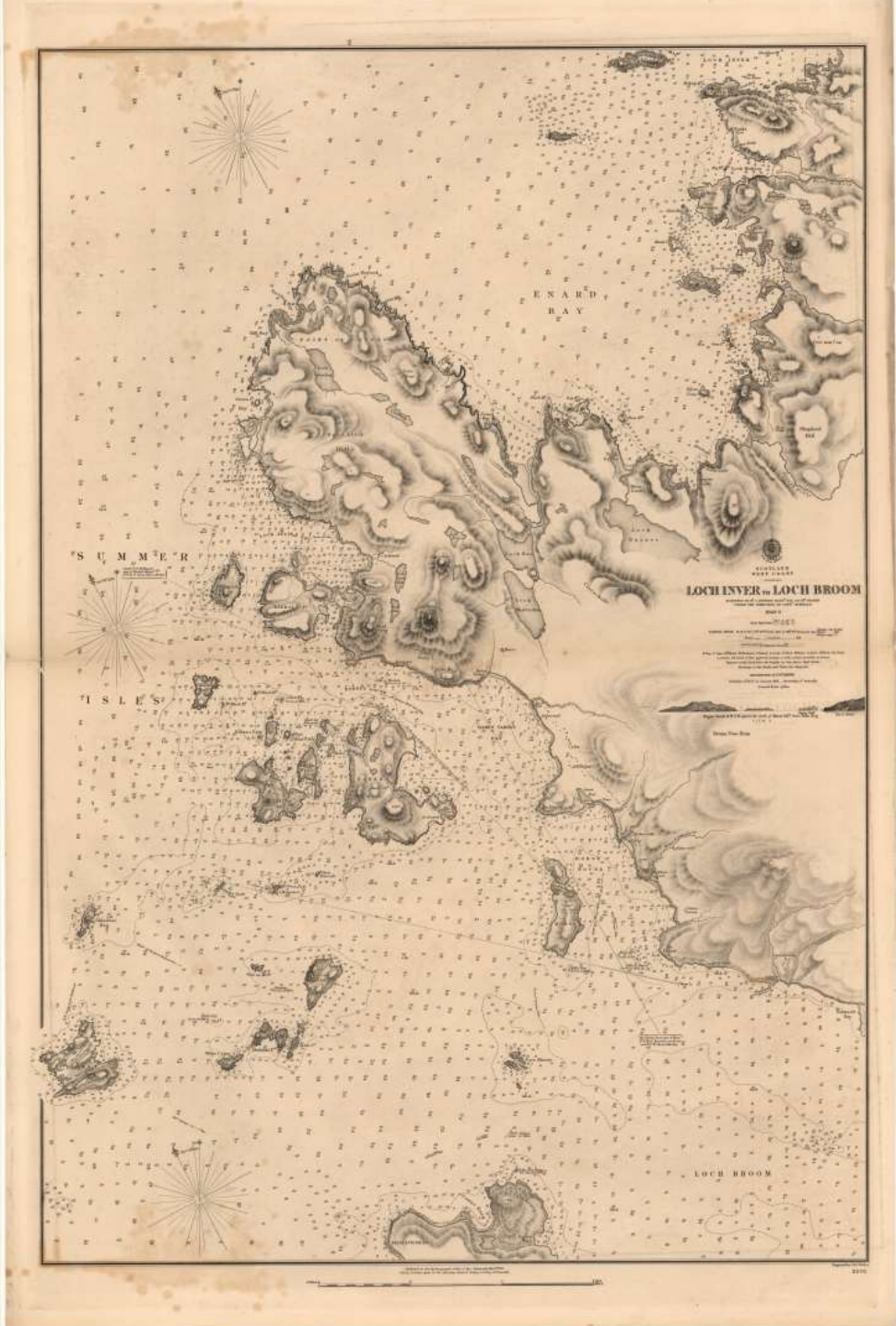
- By the 1850s vessels had been routinely crossing the ocean’s for >200 years.
- Coastlines of the main landmasses surveyed but little known about the sea deeper than a few 10s metres water depth.
- Both scientific and commercial drivers to know more.

Offshore exploration

HMS Challenger Expedition (1872-1876)

Crew and scientists of *HMS Challenger* in 1874

Hydrographic survey


ENARD BAY
S U M M E R
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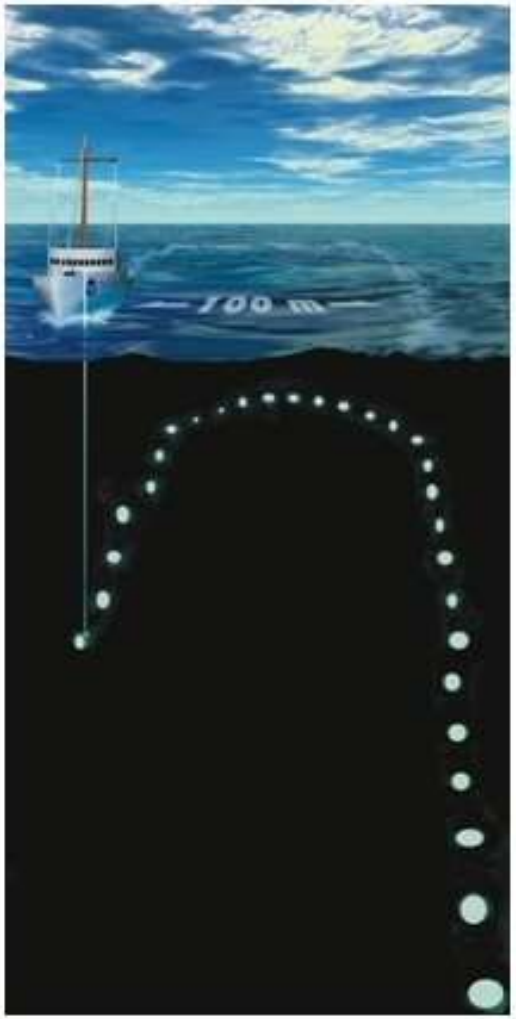
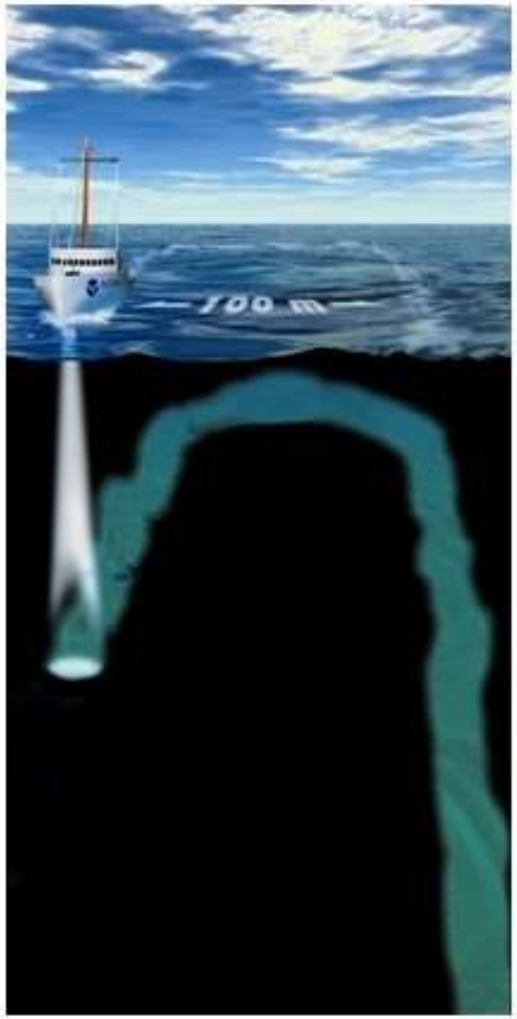
LOCH BROOM



Leadline survey



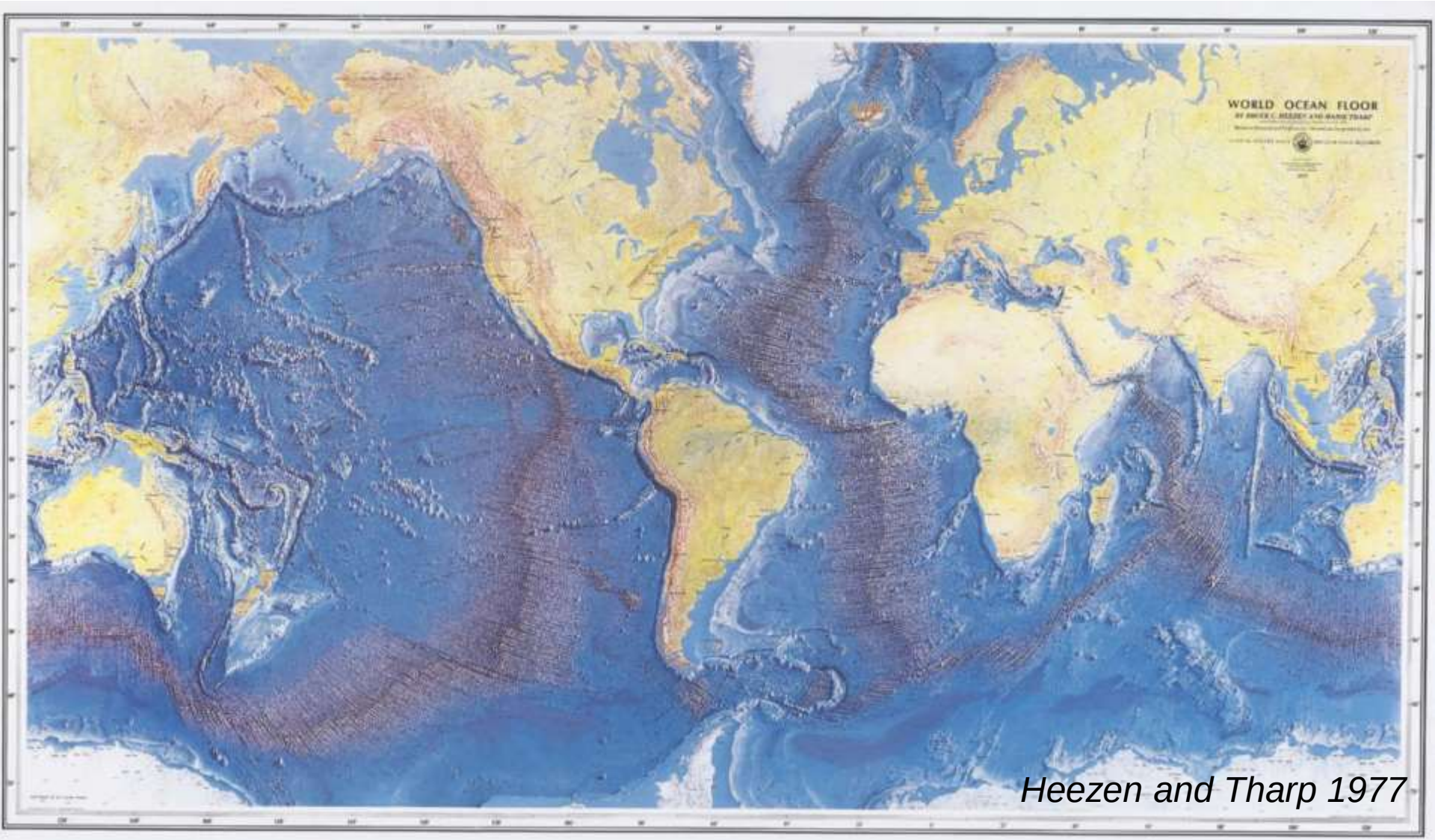
Single-beam echosounder survey

Sonar surveying brought in ~1920's

First Systematically Produced Global Bathymetric Map

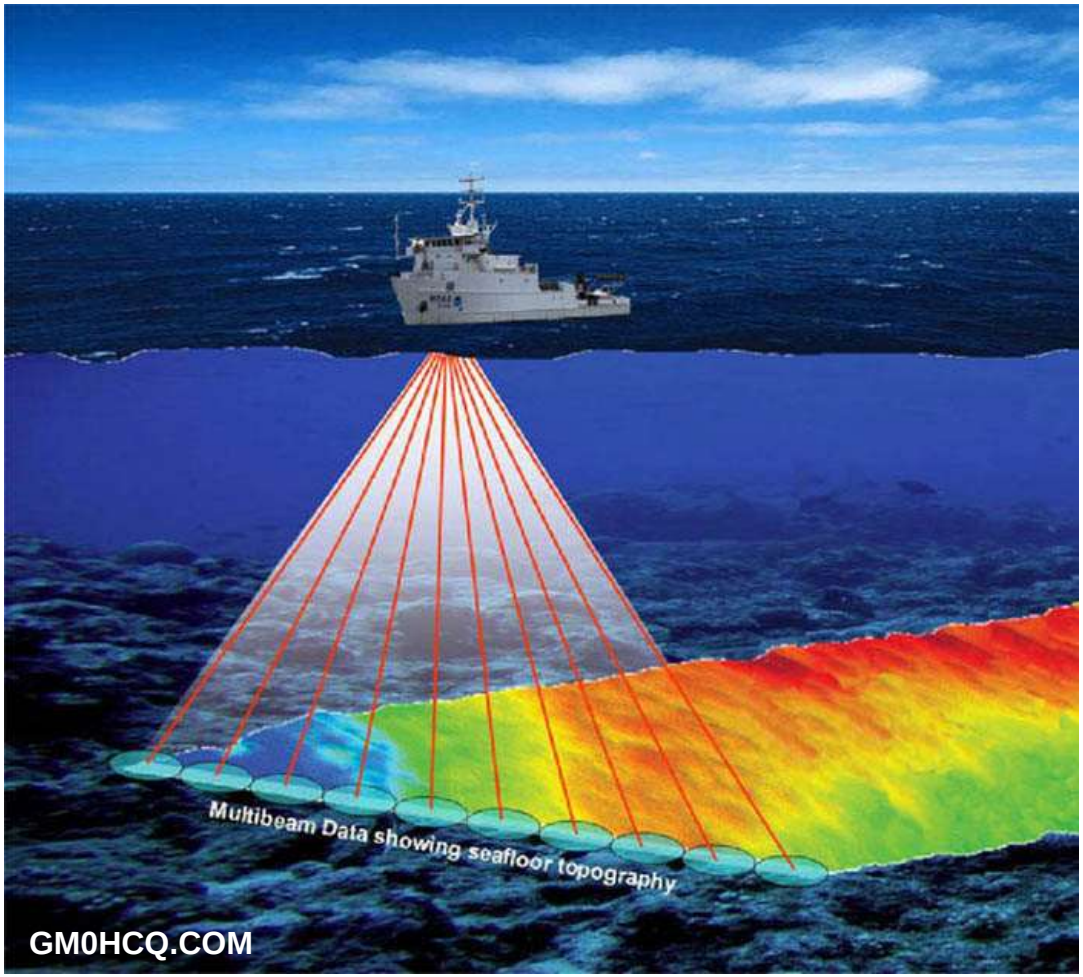
- Bruce Heezen and Marie Tharp.
- Created the first scientific map of the entire ocean floor.
- Led to acceptance of theories of continental drift and plate tectonics.

First Systematically Produced Global Bathymetric Map

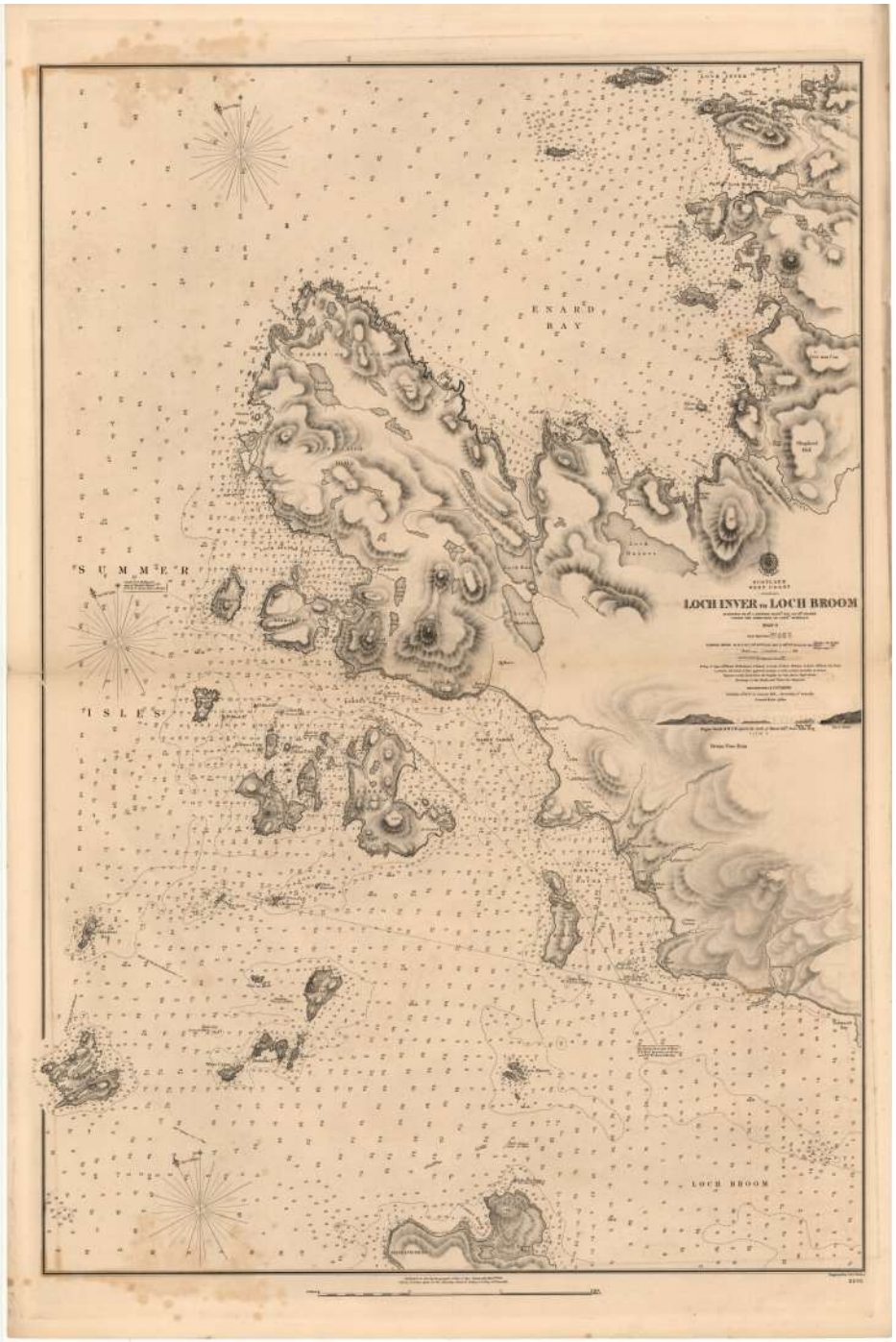


Heezen and Tharp 1977

Multibeam echosounders



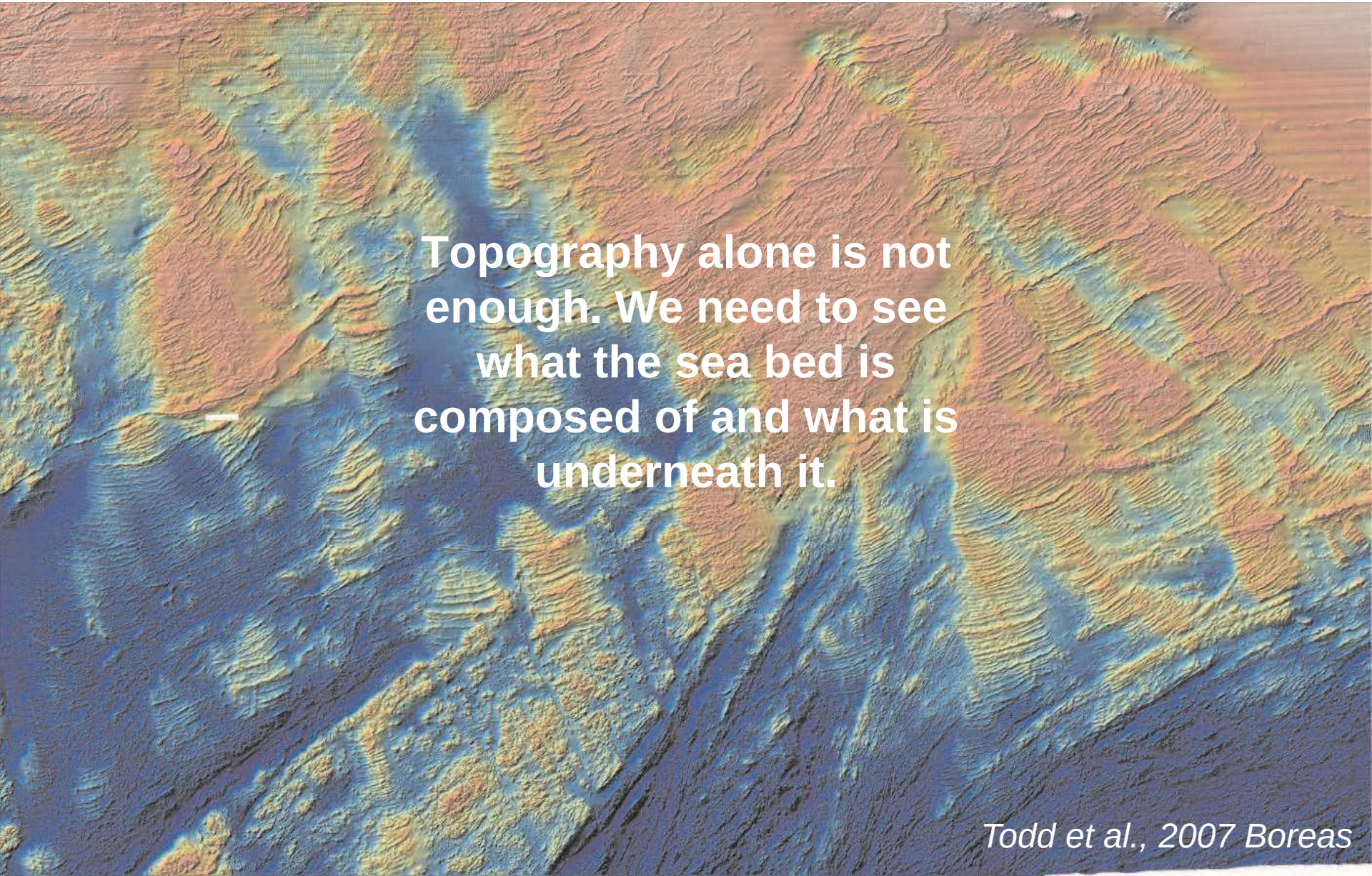
- Covers more seabed, quicker and at higher resolution.
- Ship, AUV and ROV acquired datasets.



- Evolve from point based maps and interpolation between disparate data locations.

e.g. *The Loch Inver to Loch Broom Admiralty Chart published in 1857 by the Hydrographic Office of the Admiralty. The soundings are in fathoms rather than metres.*

Full coverage of the sea floor



Seismic data

3 categories:

- Seabed to *c.* 1km below seabed.
  - Geotechnical and environmental studies.
  - Carbon Capture and Sequestration.
  - Geothermal energy.

- Up to 10km below seabed.
  - Hydrocarbon exploration.
  - Carbon Capture and Sequestration.

- Crustal studies at depths of up to 100km below seabed.
  - Studies into structure and origin of Earth's crust.

Seismic data

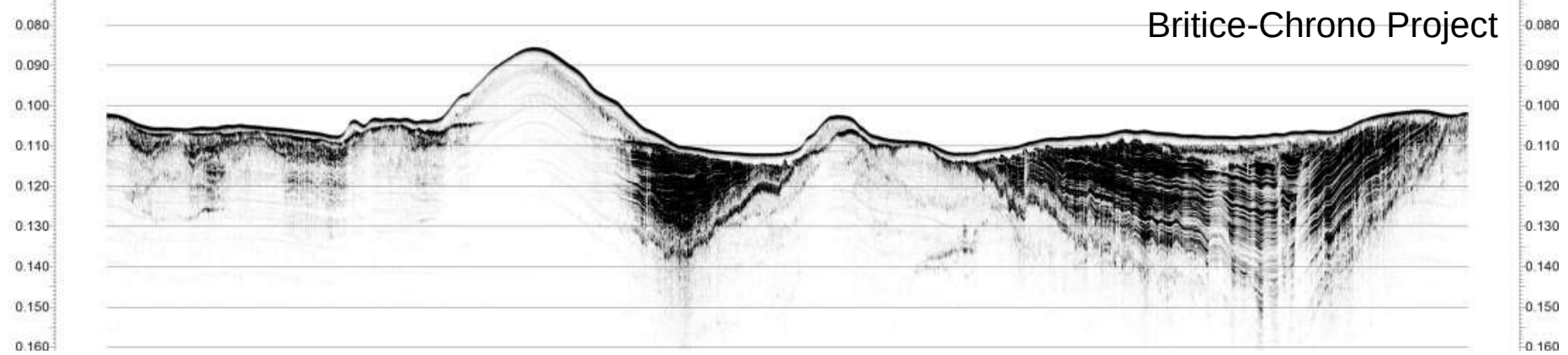
Dynamite or oxyacetylene used in early exploration.

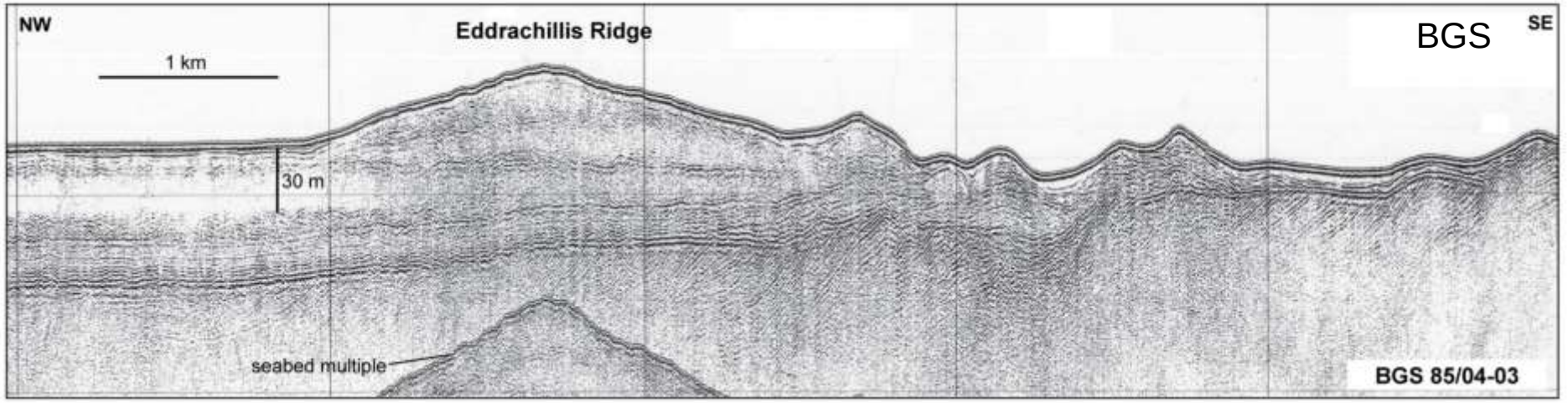
Airgun array, BGS

Compressed air or electrical source used routinely today.

3D seismic where sources and receivers laid out in a grid.

Britice-Chrono Project



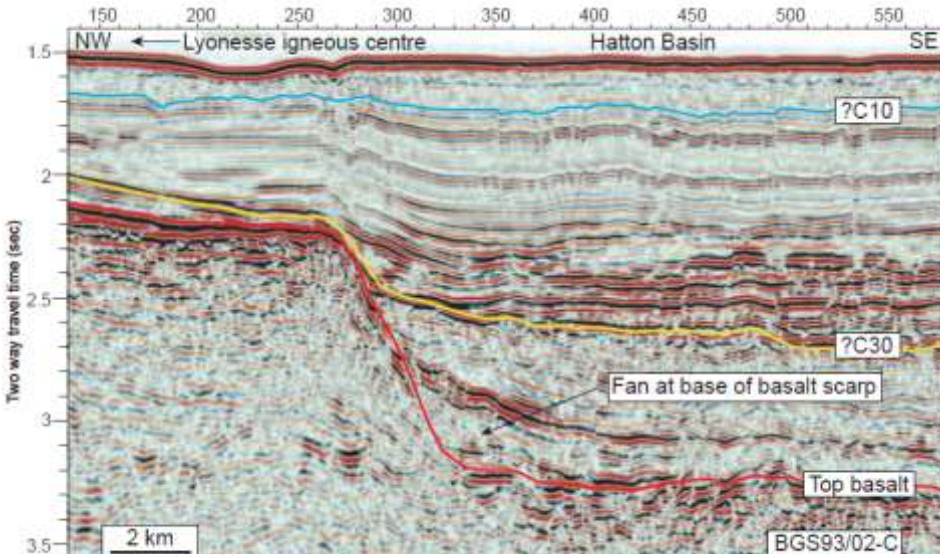


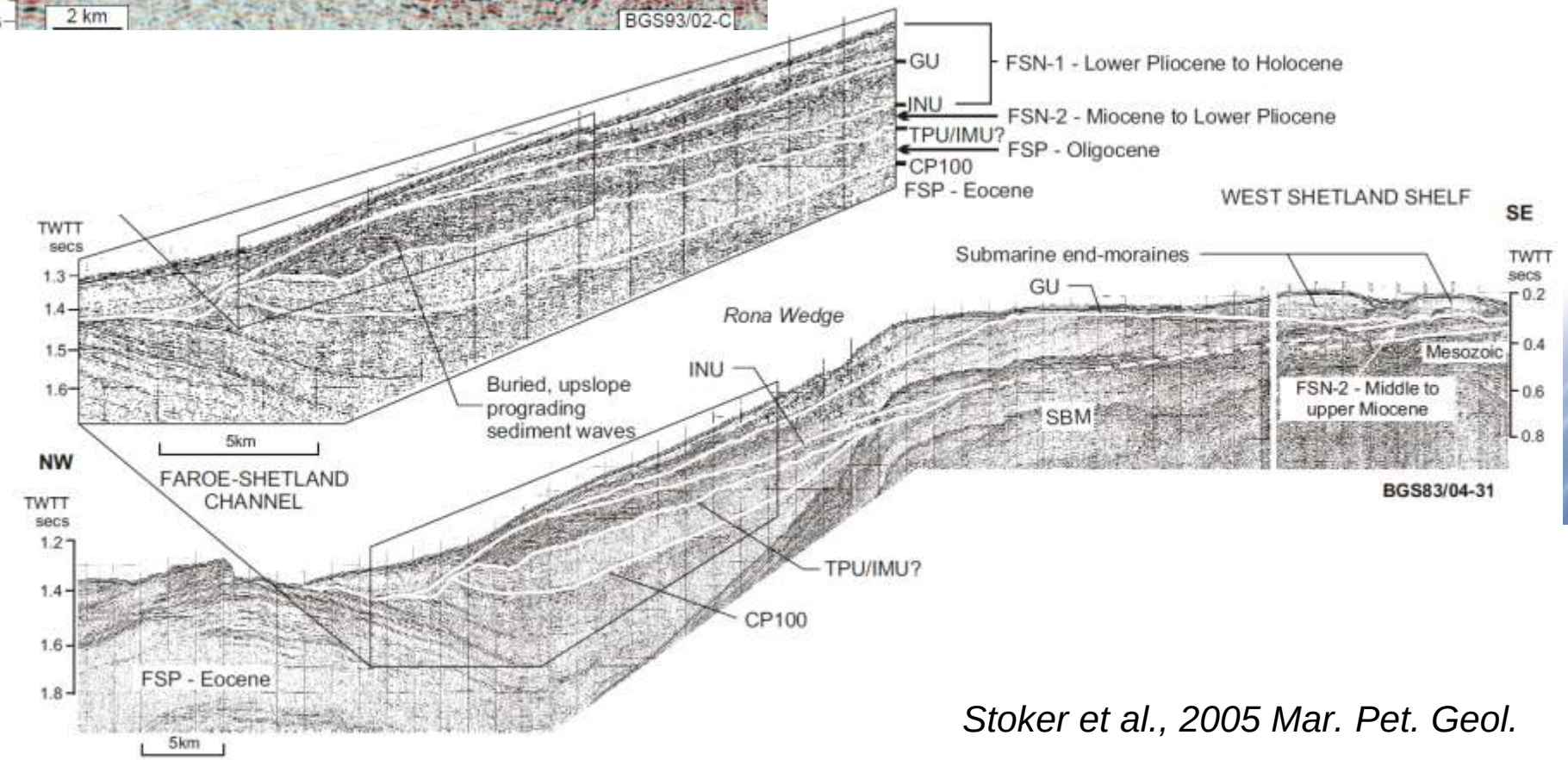
BGS

Bradwell & Stoker 2015 Boreas

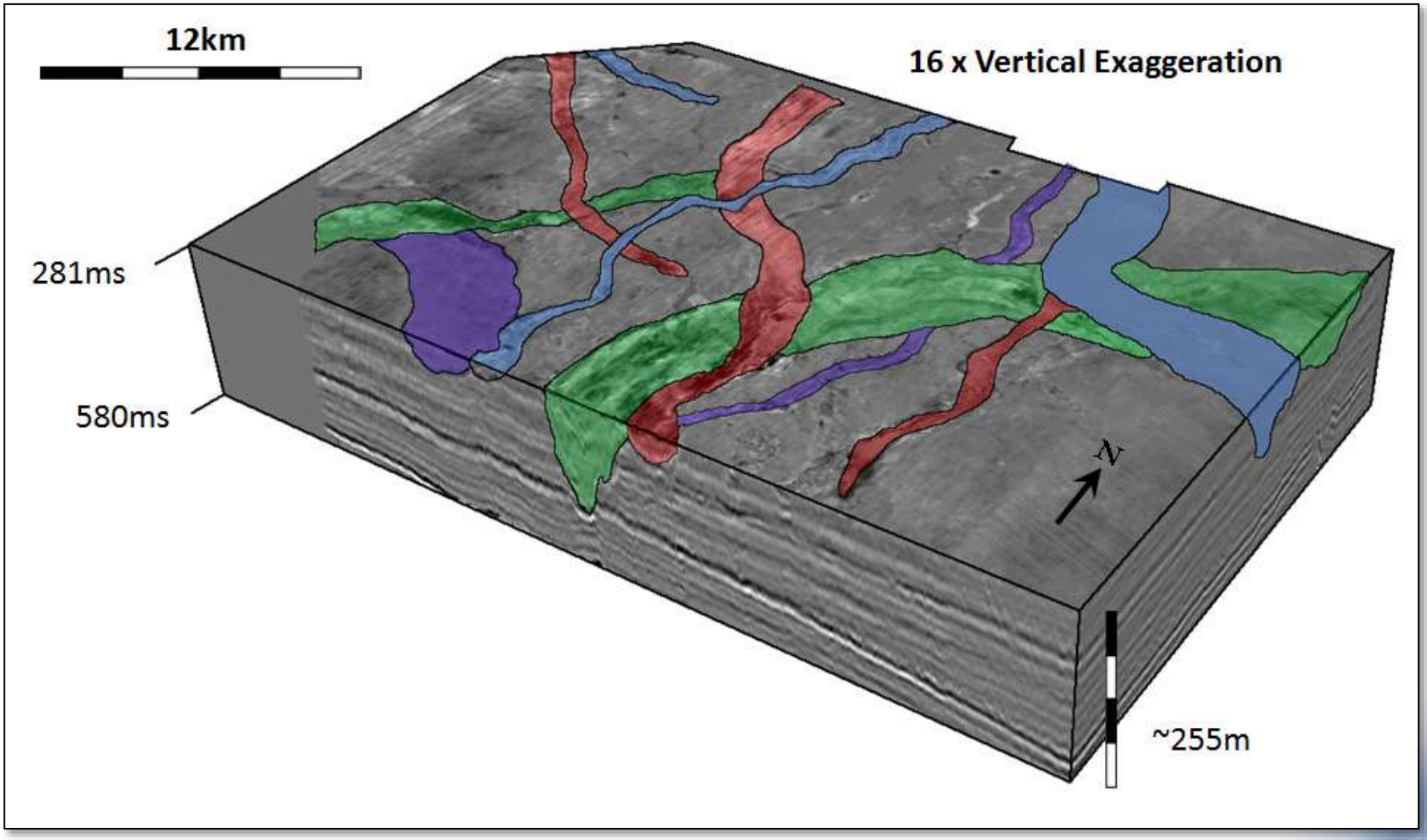
McInroy et al., 2006

Geol. Soc. Lon. Spec. Pub. 254





Stoker et al., 2005 Mar. Pet. Geol.



Stewart et al., 2013 QSR

High resolution 3D seismic allows you to image geomorphology at multiple sub-sea bed horizons

Offshore sampling

International Ocean Discovery Program
2013-2023

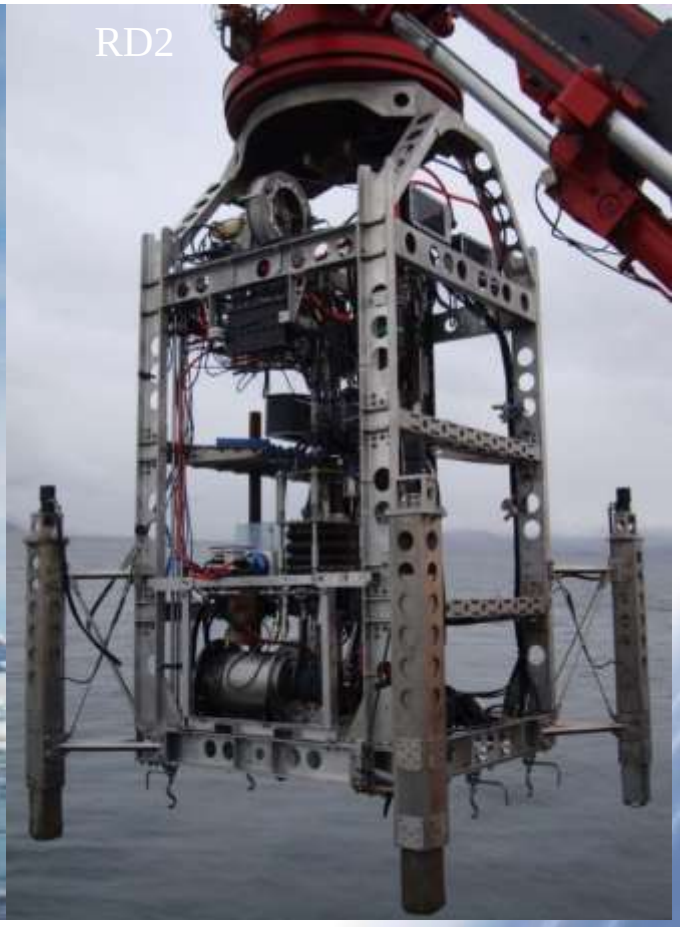
Scientific ocean research drilling

Vibrocorers and rockdrills

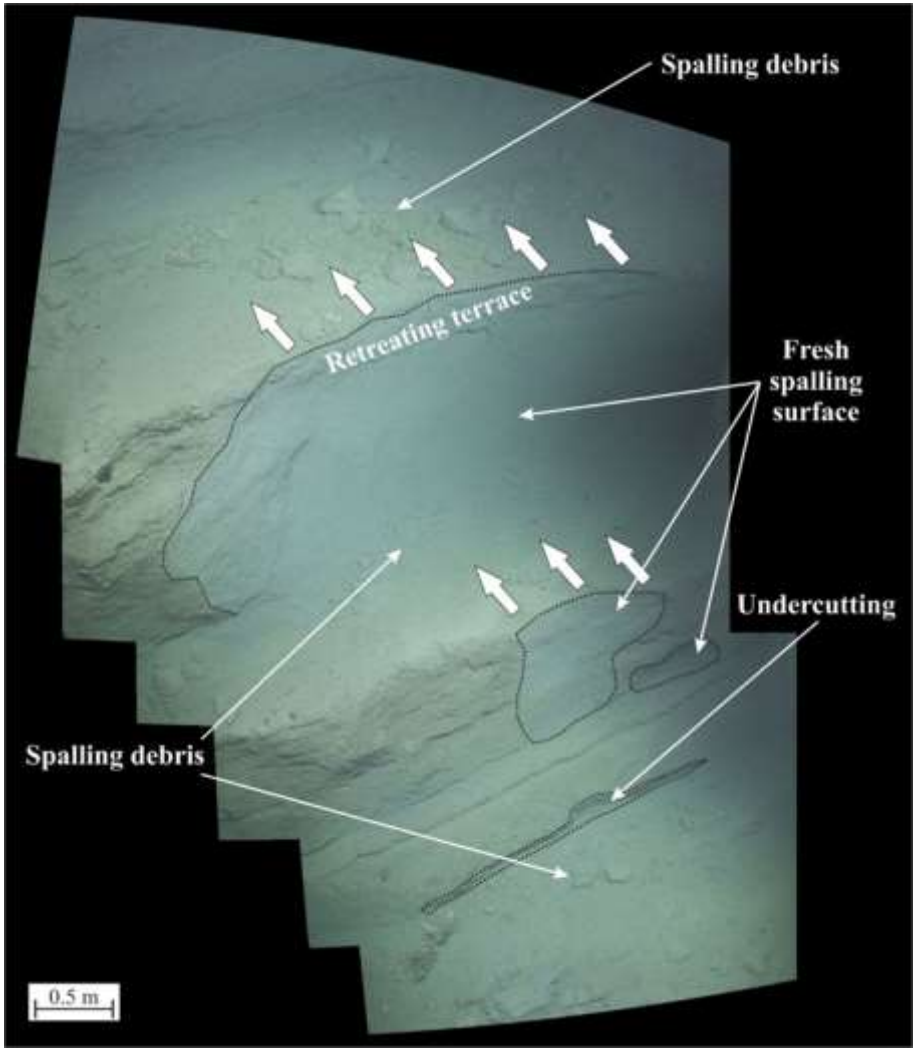

Oriented Drill


3m Vibrocorer

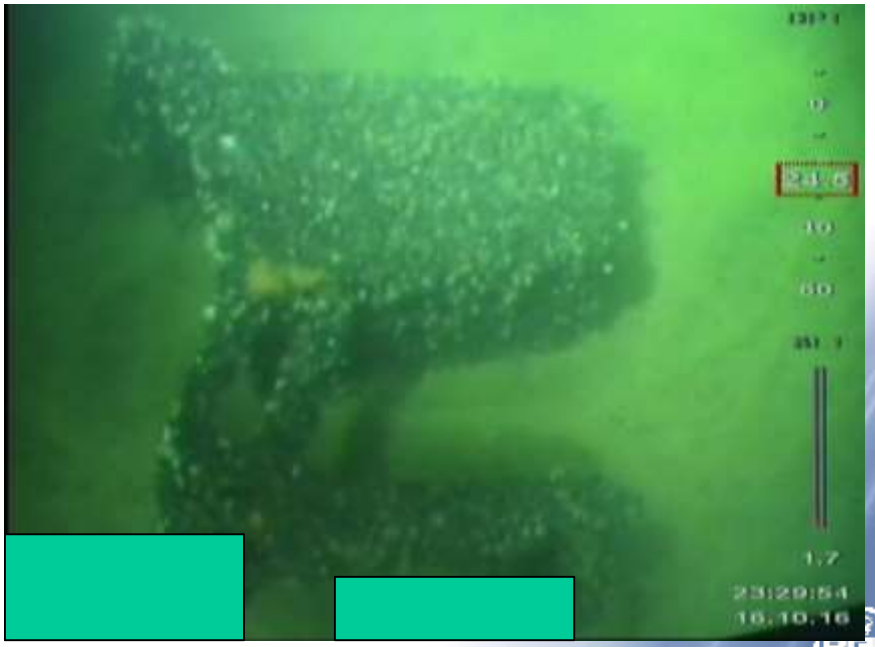

RD1/6m vibrocorer


RD2

Other visual sampling techniques



- Spalling failure leading to almost continuous erosion of mudstone cliffs; can result in undercutting of more competent bedrock units.
- Relatively rapid erosion results in poorly colonised slopes, as benthic communities do not have time to colonise face.



Carter et al., submitted

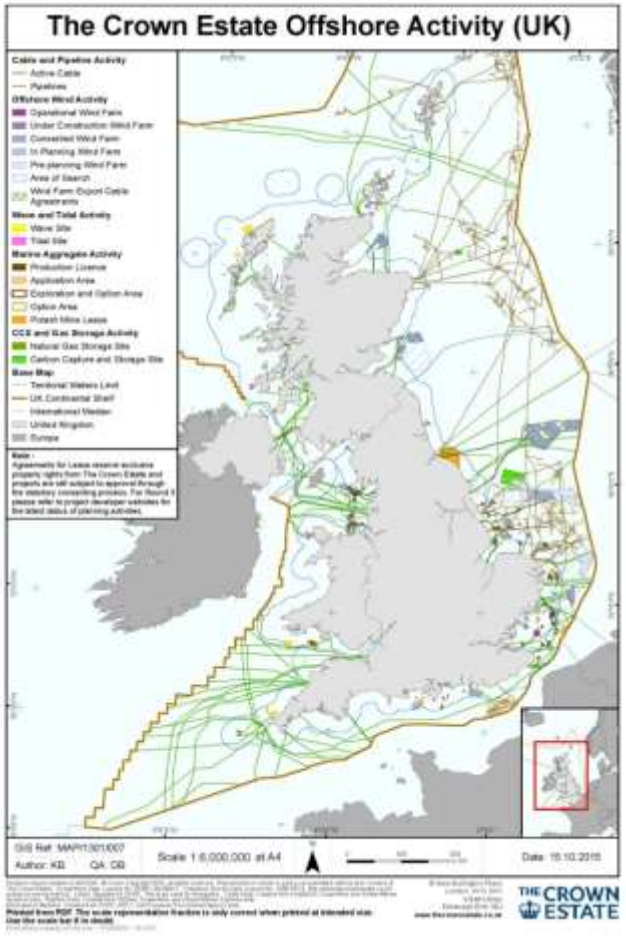
Data acquired as part of CODEMAP project

Why map?

- ***Understand the environmental processes which formed and actively govern the marine environment.***
- ***Prospect of significant scientific discovery!***

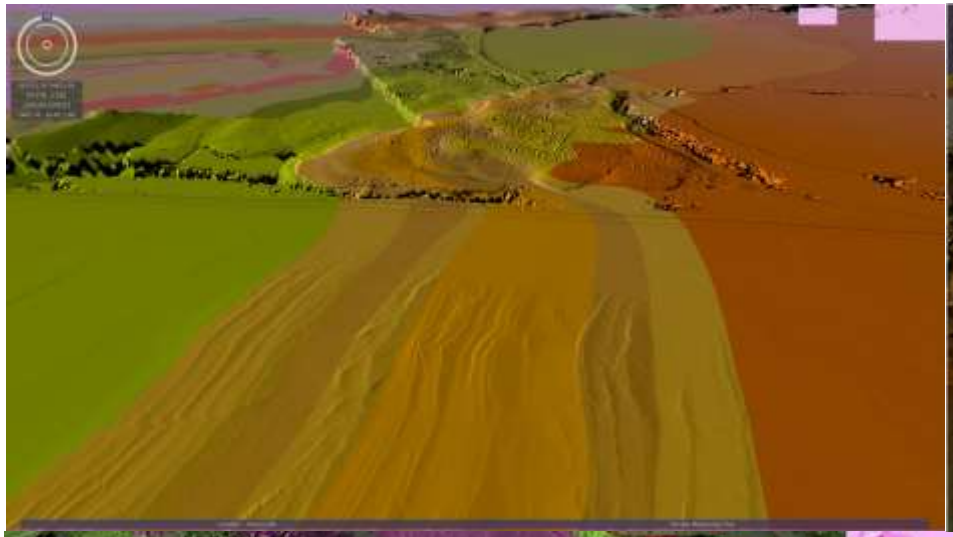
- **Aggregates and Minerals**
- **Biology**
  - Habitat mapping and Marine Protected Areas
- **Commercial**
  - Offshore Renewables
  - Oil and Gas infrastructure
- **Geohazards**
  - Shallow gas, submarine landslides
  - Coastal erosion

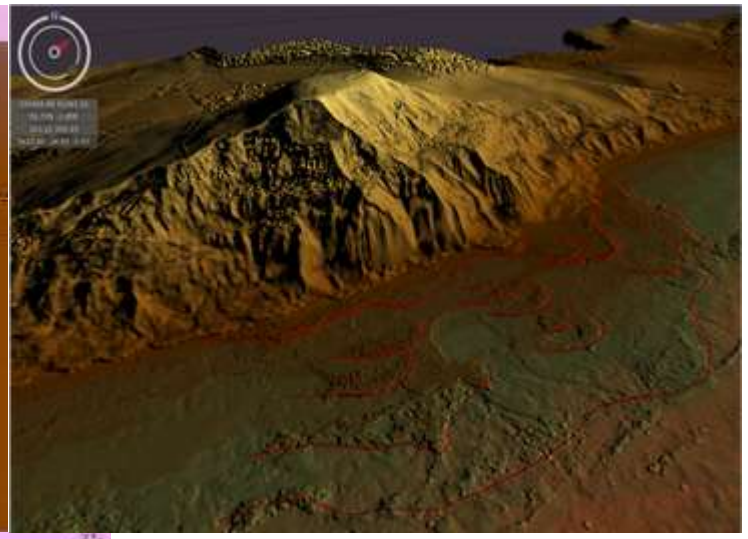
- **Marine Archaeology**
  - Paleaolandscapes
  - Wrecks
- **Political**
  - Law of the Seas
- **Scientific**
  - Climate History and active environmental dynamics
  - Tectonics, mantle dynamics

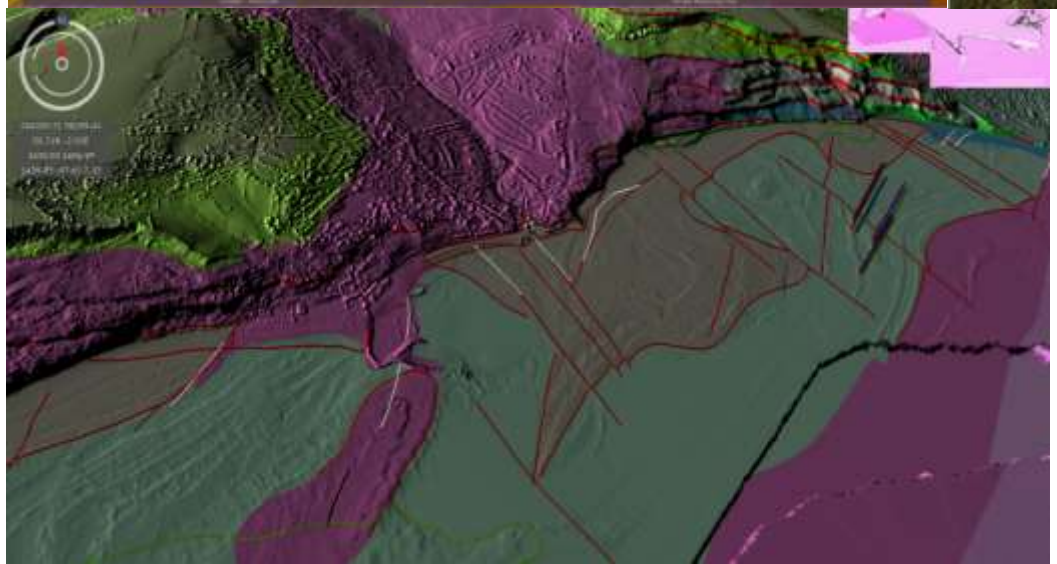


Seamless Onshore-Offshore Mapping

- Offshore – ship-based Swath Bathymetry (5m)
- Onshore and intertidal zone – airborne LIDAR (1m)

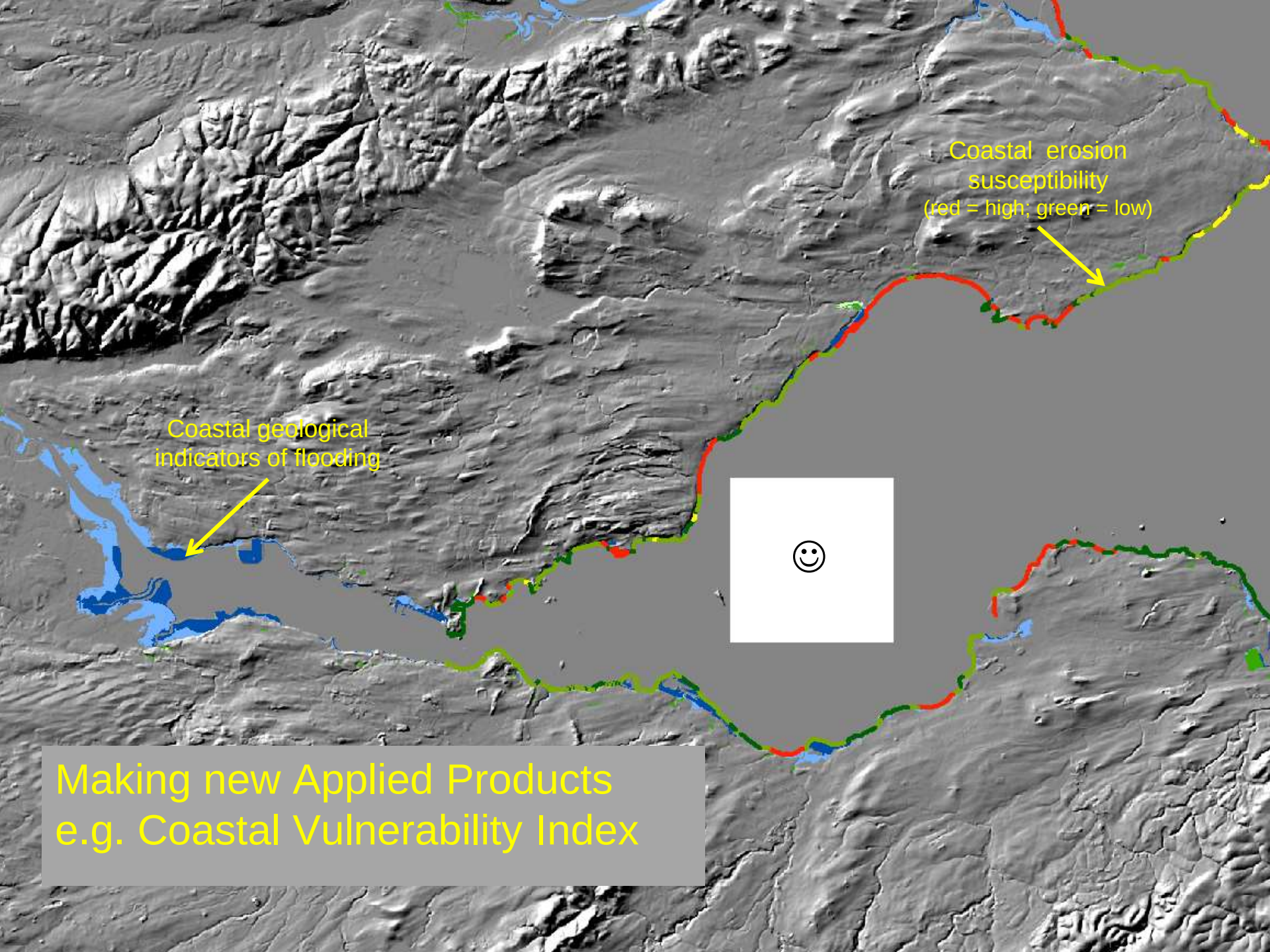






e.g.
Onshore-Offshore – 10k
Bedrock mapping

Slope stability



Making new Applied Products e.g. Coastal Vulnerability Index

Submerged landscapes

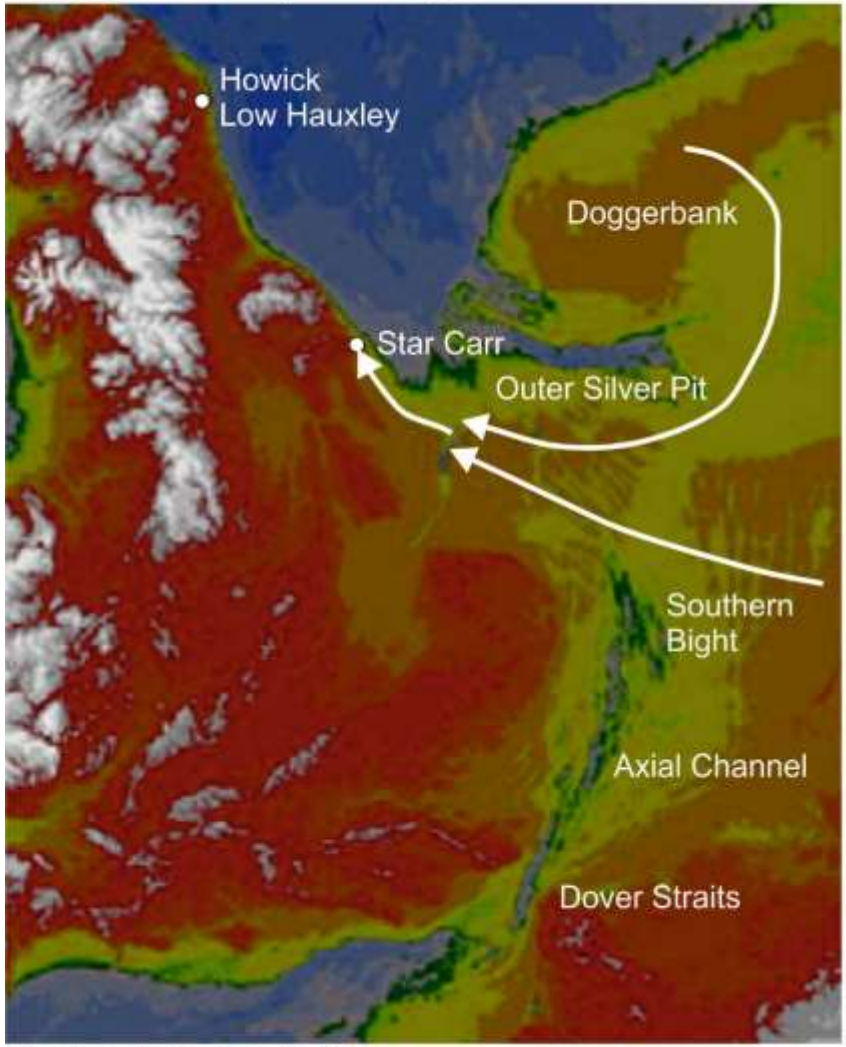
Submerged landscapes is an emerging integrated discipline linking climate, sea level and environment change to the people who lived and migrated across the continental shelf.

New workpackage in the next phase of EMODnet 2017-2019(2021)
Holocene thickness, sea-level, dates, geomorphology and palaeogeography

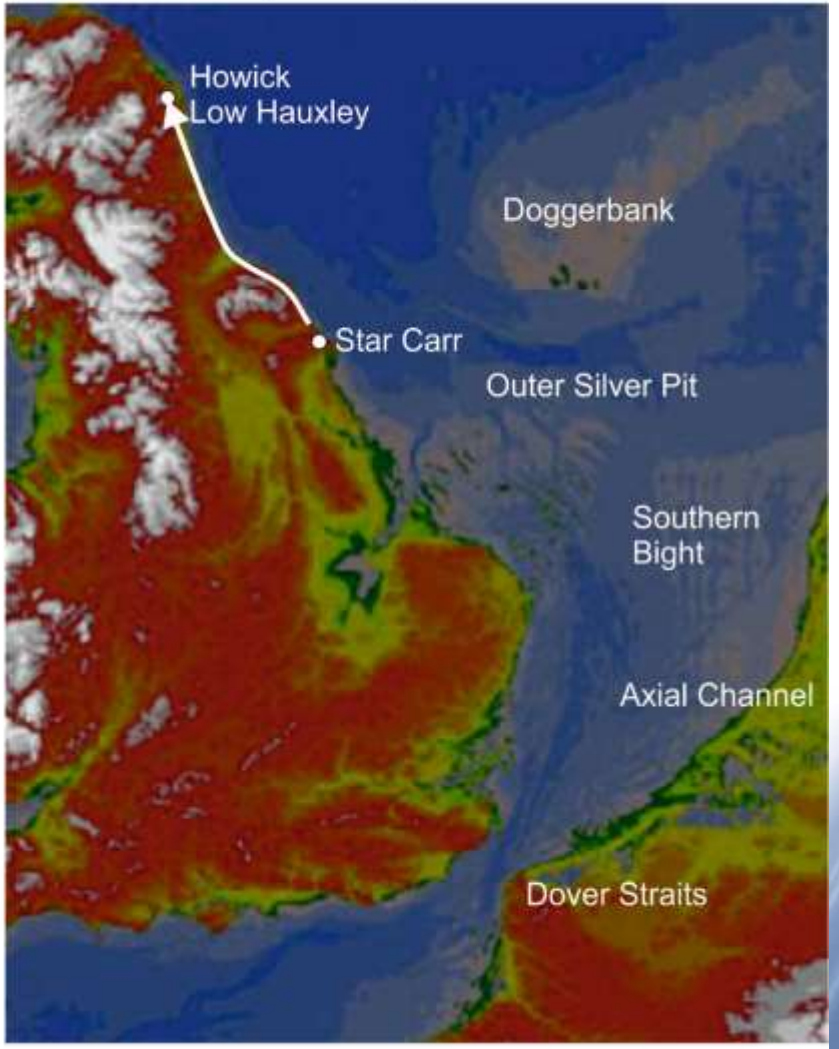
C. Mellett

Palaeogeography and migration

Early Mesolithic (ca. 11 ka)



Late Mesolithic (ca. 7 ka)



Modified after Sturt et al., (2013)

Submerged landscapes and archaeology

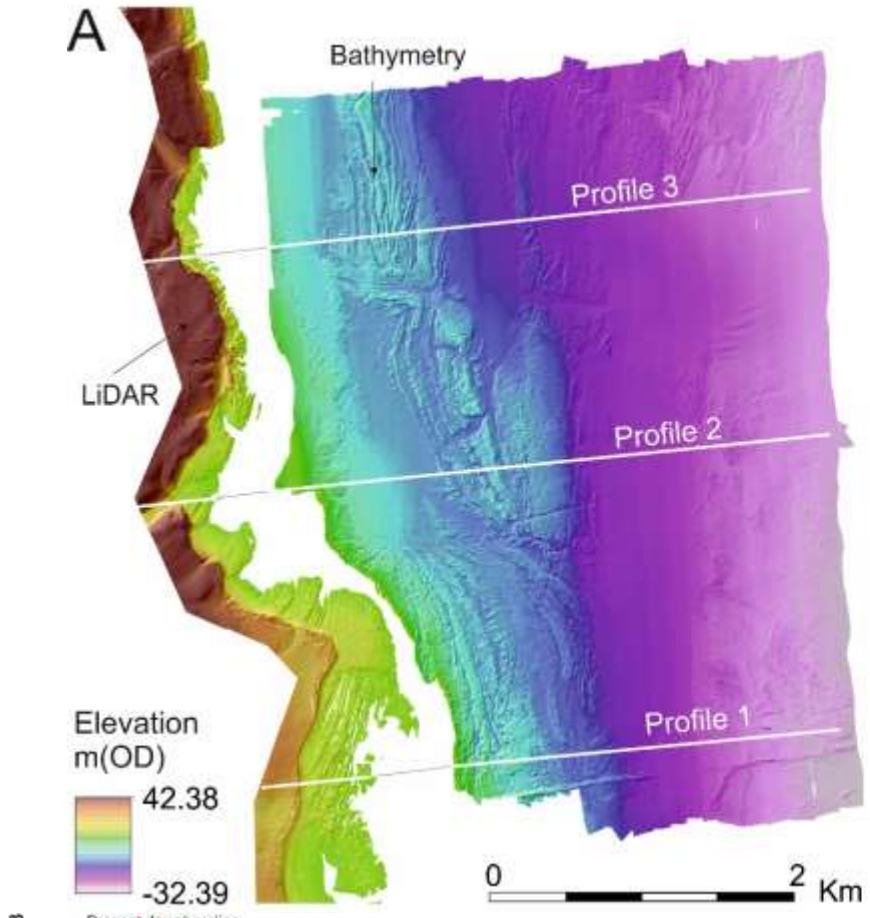
- What was the landscape during occupation of this settlement?

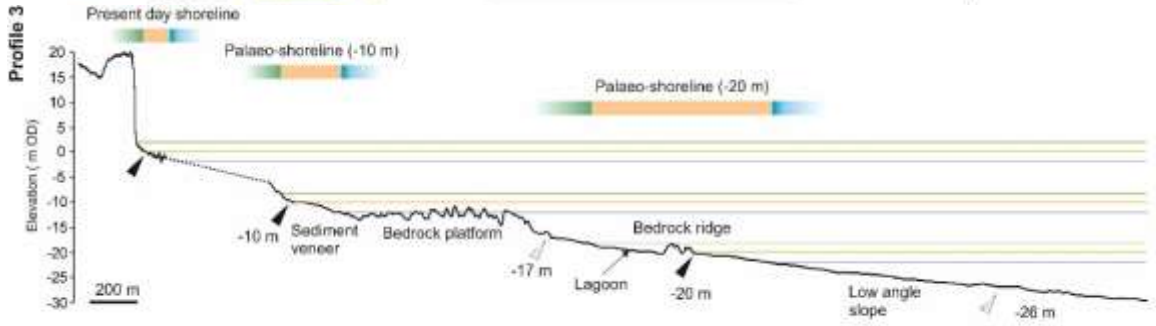
Mesolithic site at Howick

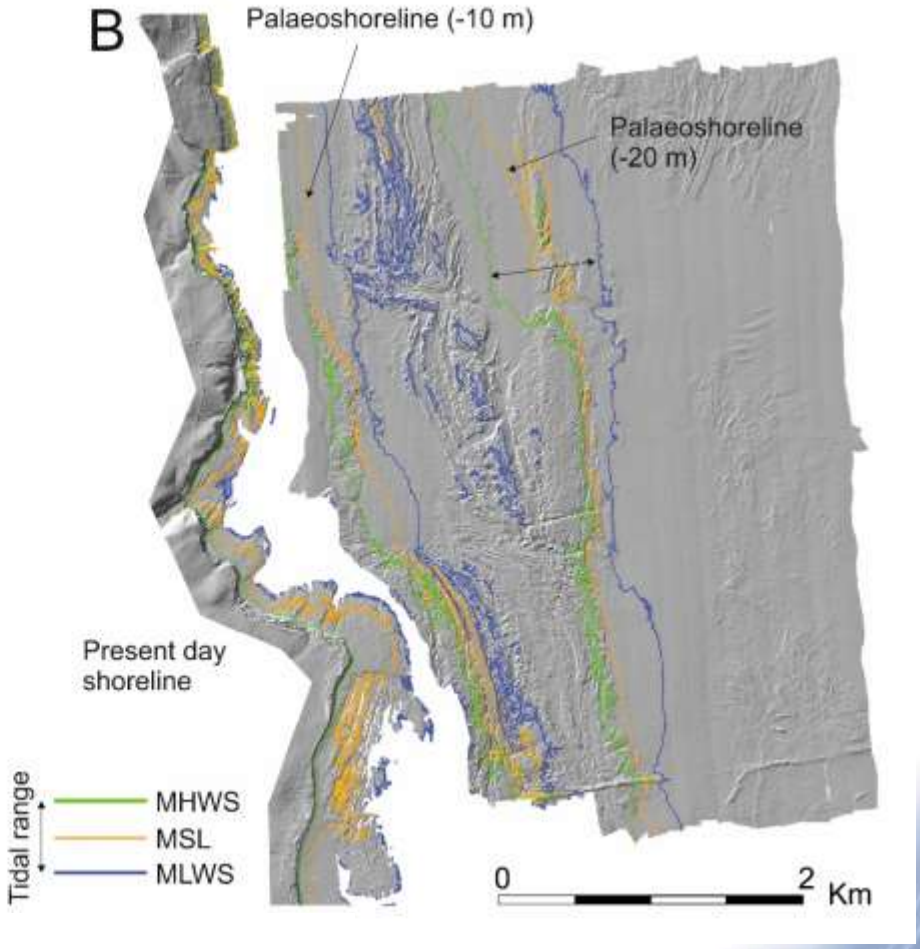
C. Mellett

Human interaction with the landscape

ENGLISH HERITAGE







Mellett & Plater 2016

Submerged landscapes and archaeology

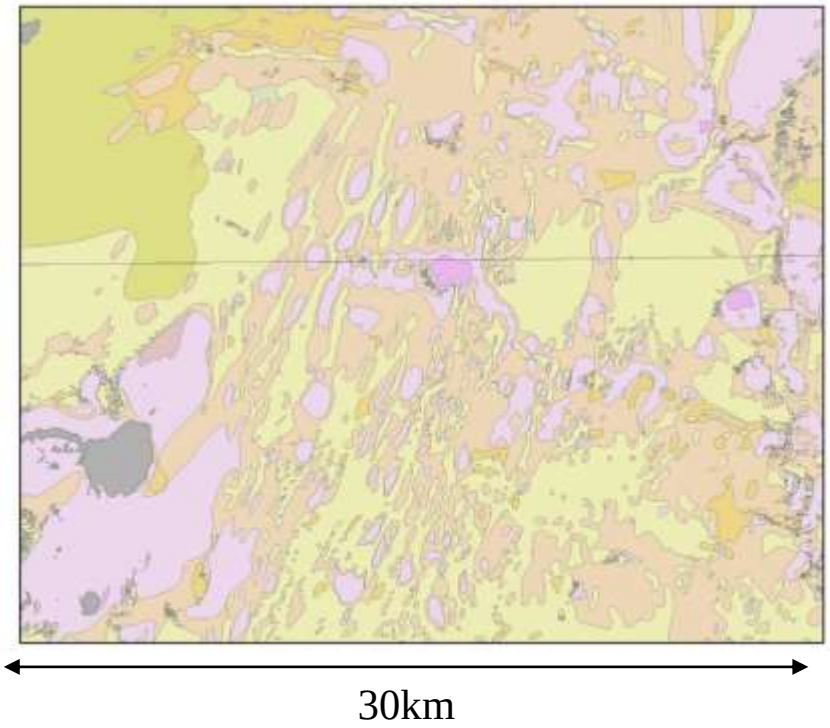
- Series of palaeoshorelines, tied with sea-level data used to reconstruct palaeogeography

- Reconstructions show the extent of the tidal flat decrease as sea-level rises (running out of food?)

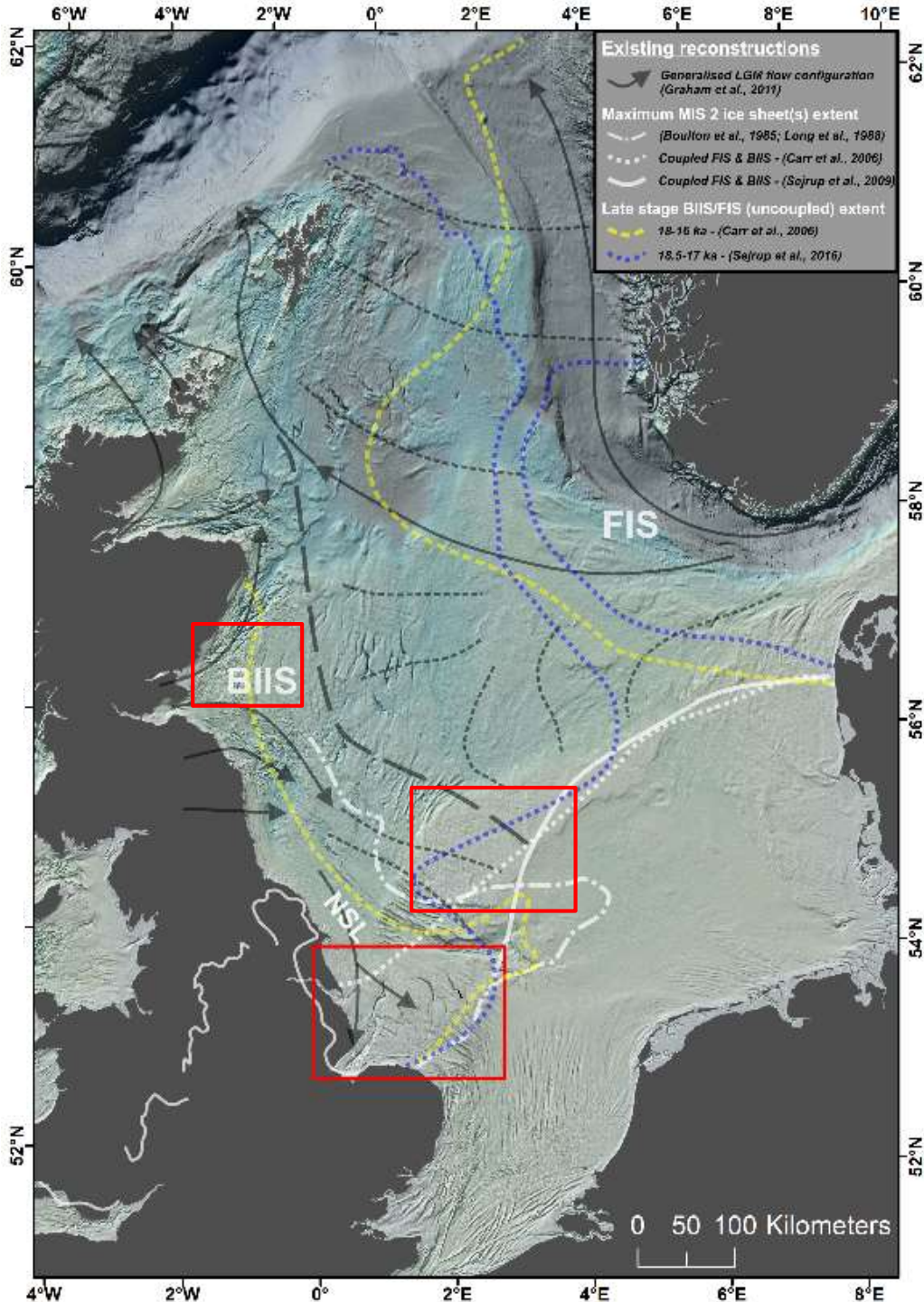
Mesolithic site at Howick

Mellett & Plater 2016

Climate change

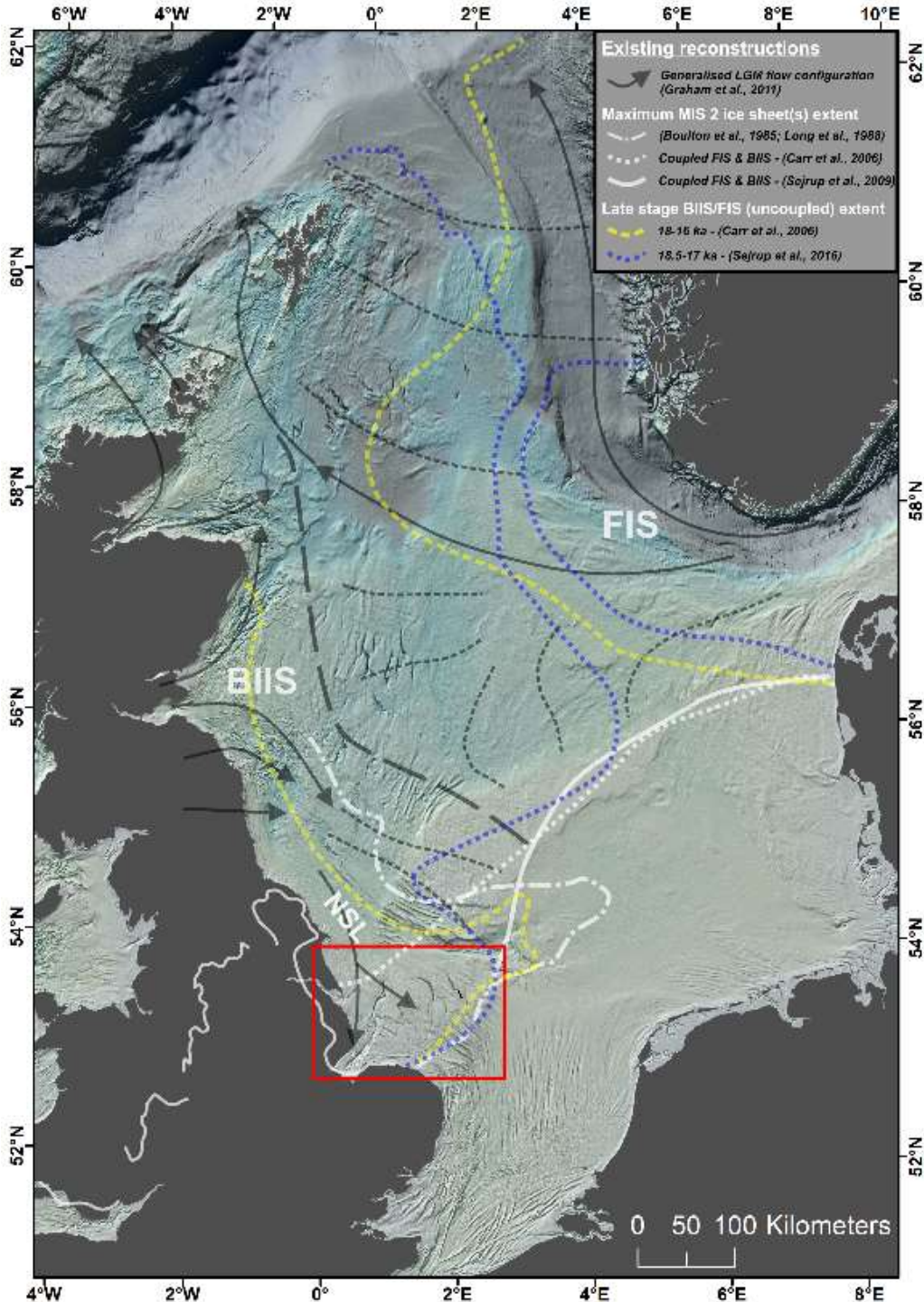


30km

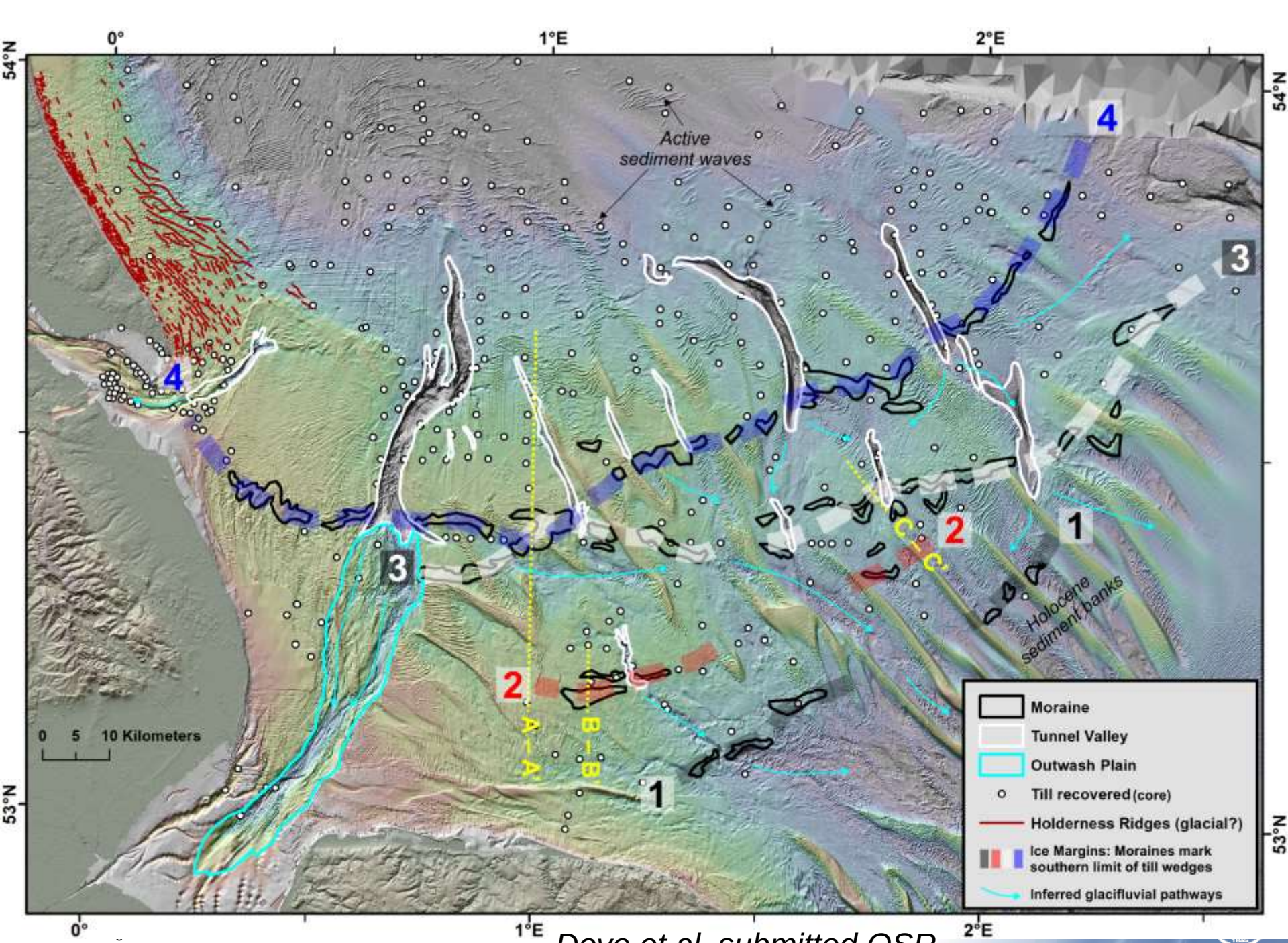


Stewart et al., submitted

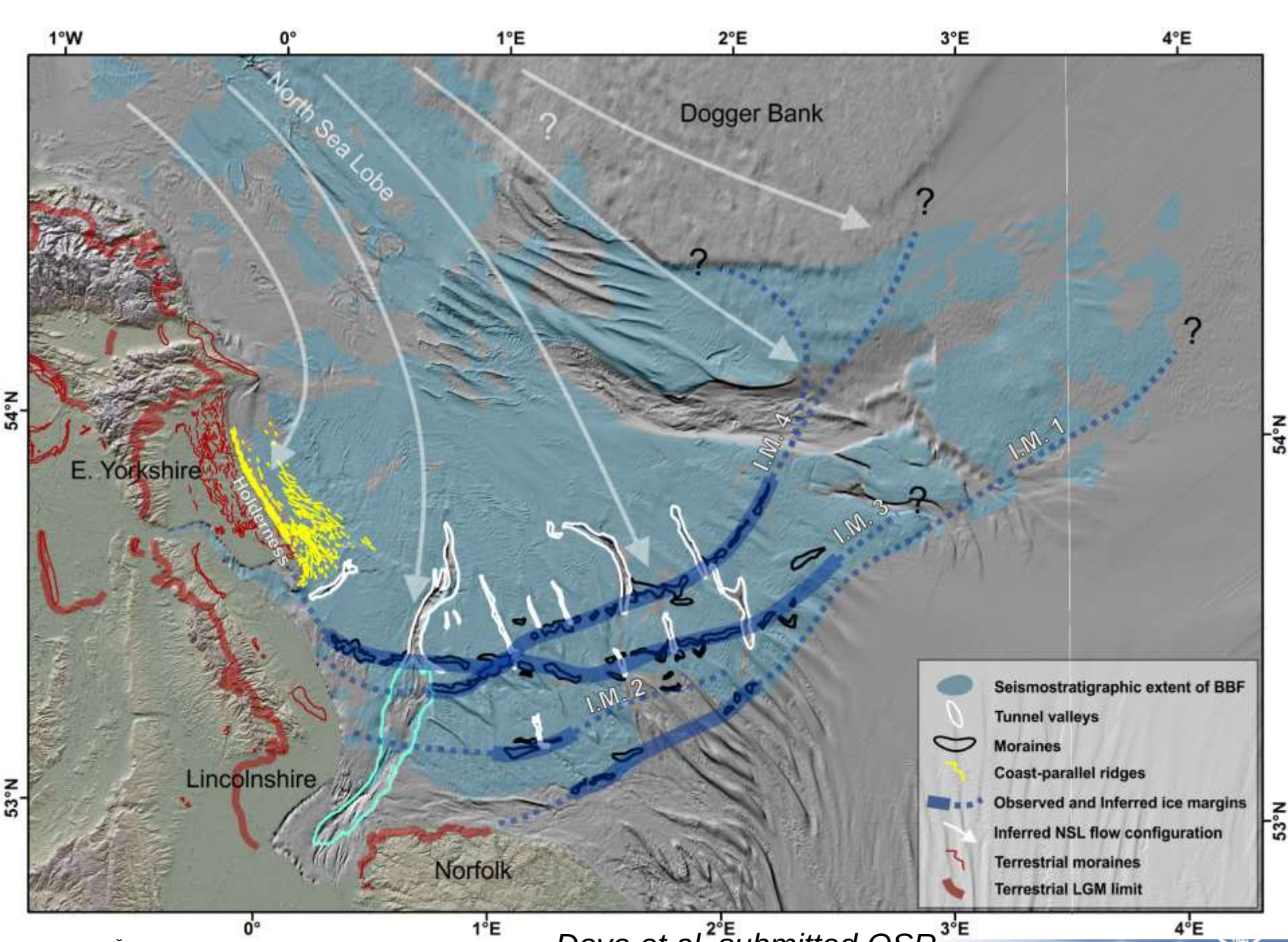
Southern extent North Sea Lobe



Dove et al., submitted



Dove et al. submitted QSR



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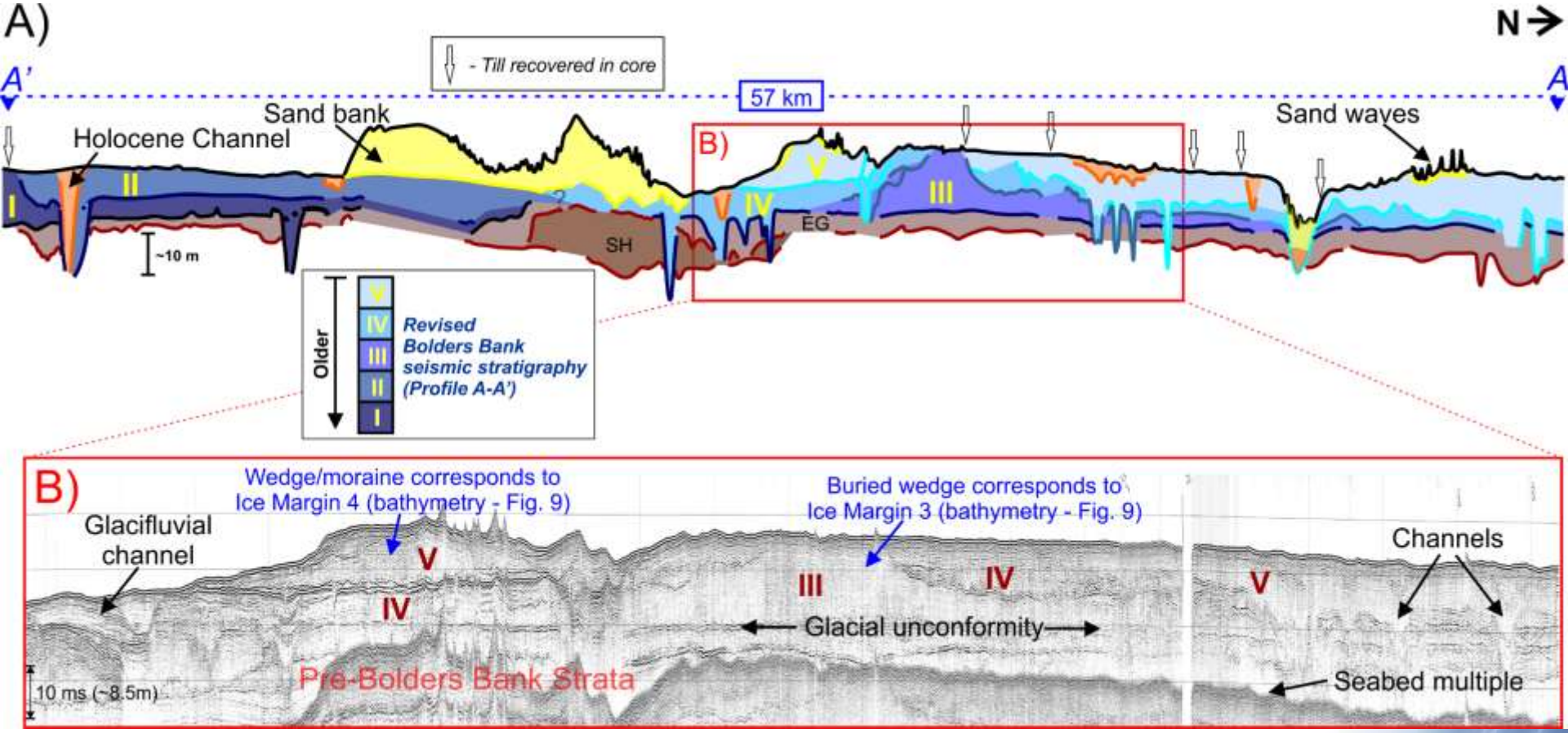


Dove et al. submitted QSR

Kviarjokull *(David Evans, Durham University)*

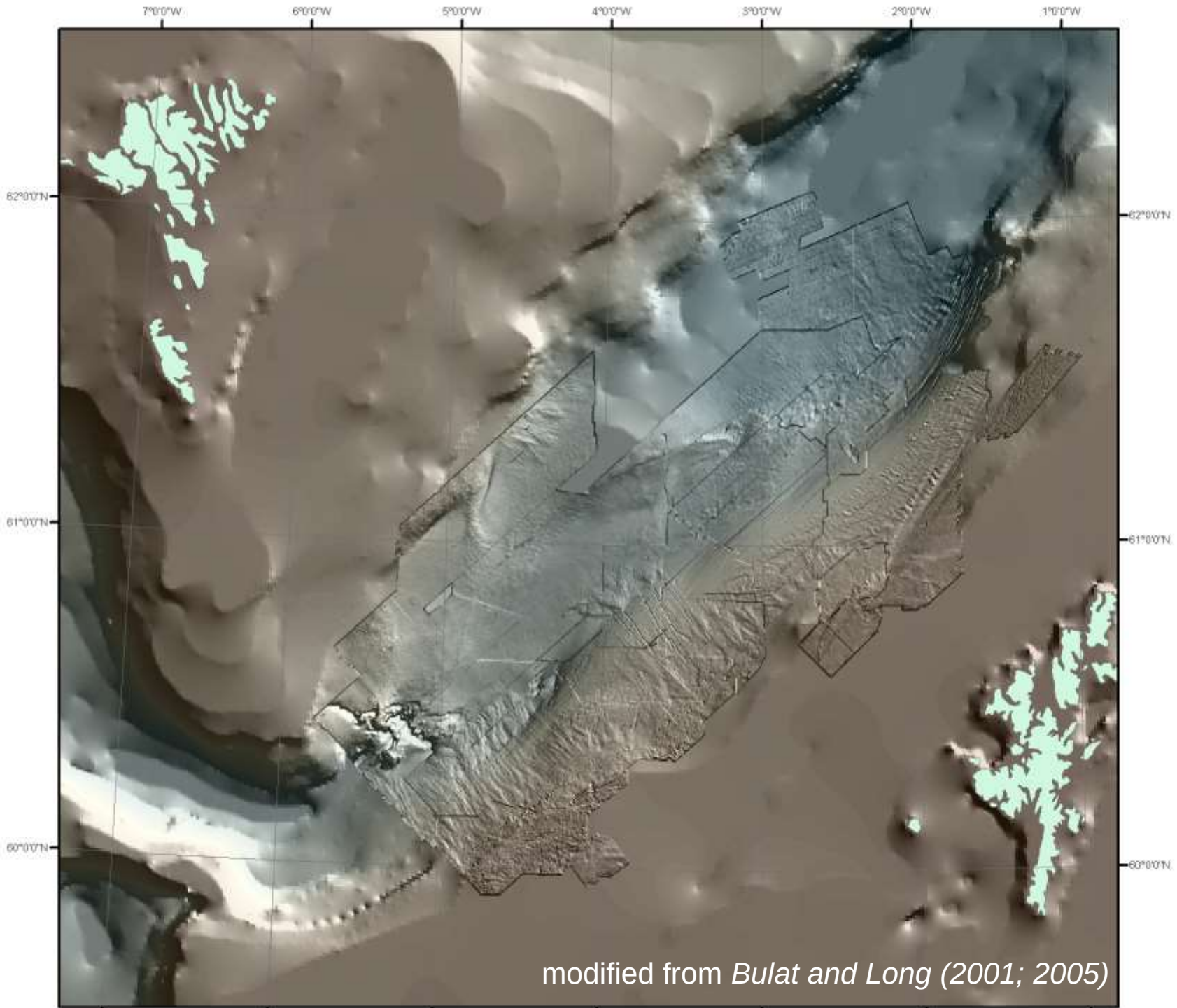
Ice extending to the continental shelf break

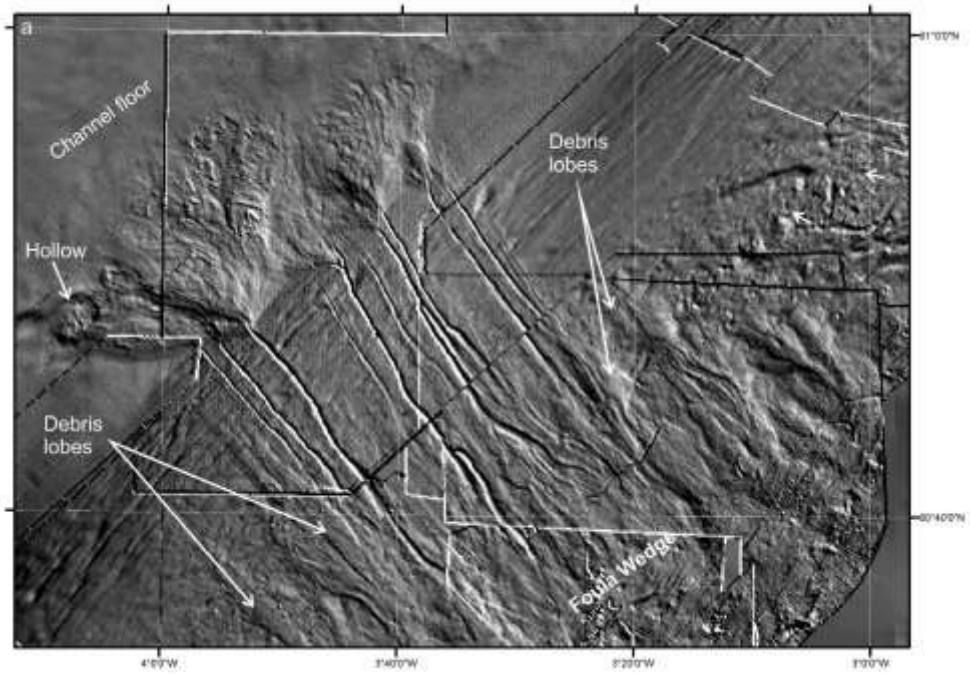
Bradwell et al., 2008

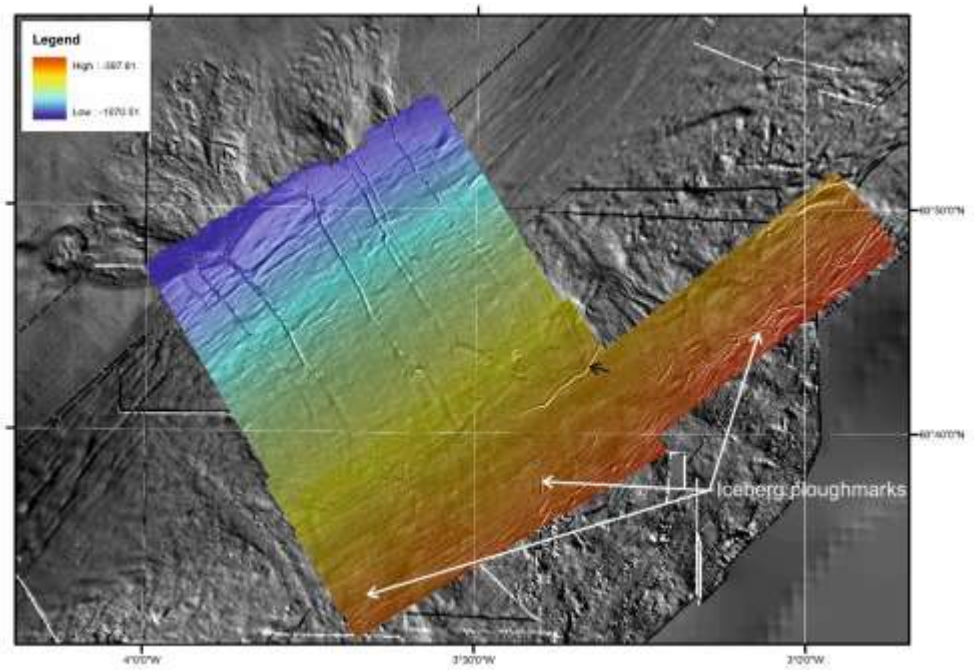
Bradwell et al., 2008

Marine terminating glacier

H. A. Stewart (BGS)


7°0'0"W
6°0'0"W
5°0'0"W
4°0'0"W
3°0'0"W
2°0'0"W
1°0'0"W
62°0'0"N
61°0'0"N
60°0'0"N
modified from *Bulat and Long (2001; 2005)*





Faroe-Shetland Channel Gullies

Found between 465m and 995m water depth.

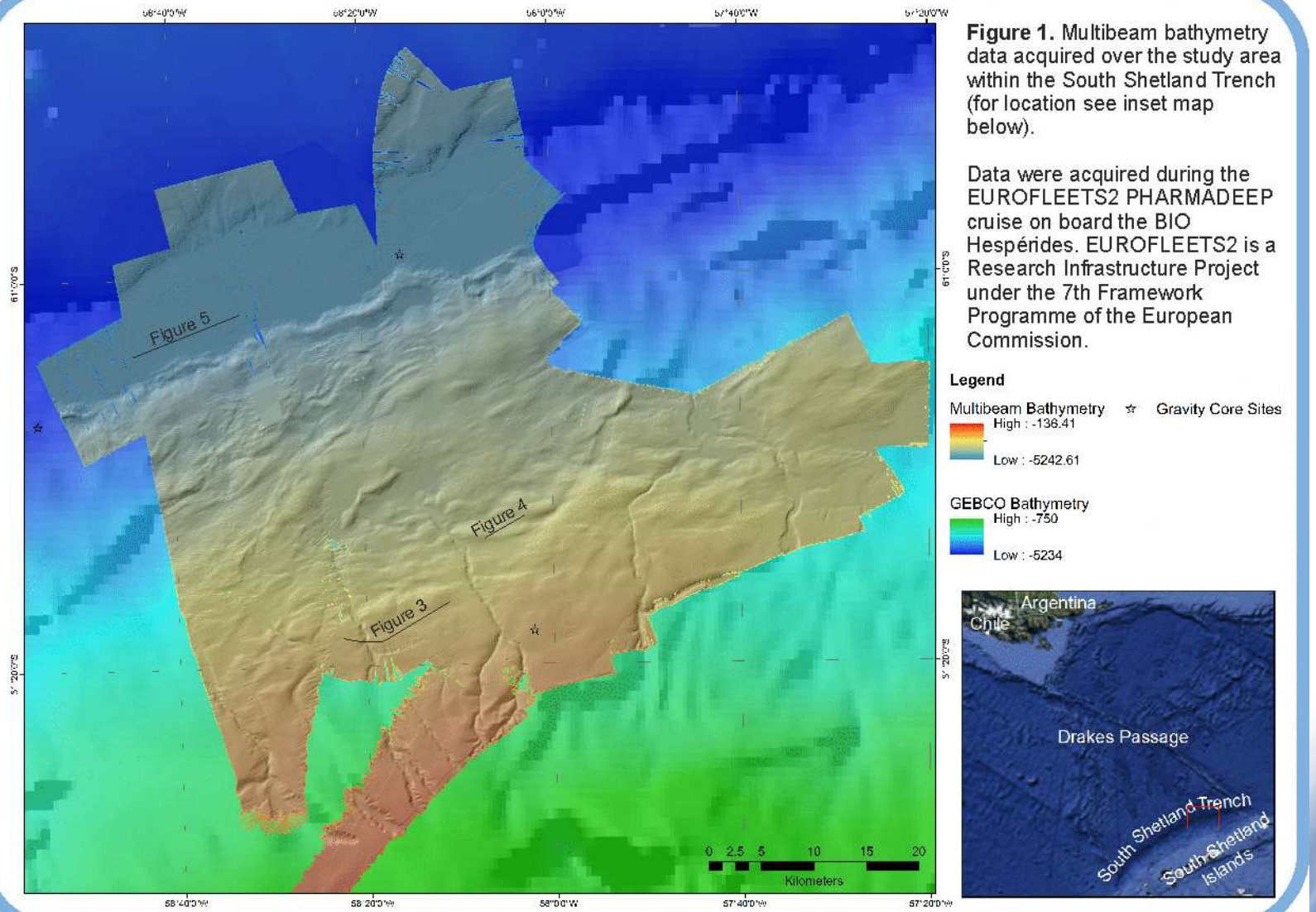
20 individual gullies imaged.

Maximum depth is 42m below sea bed.

Slope angles within the gullies locally exceed 20°.

Stewart & Long, 2012 NSG

Comparison with Antarctic margin



South Shetland Trench. Stewart et al., in prep

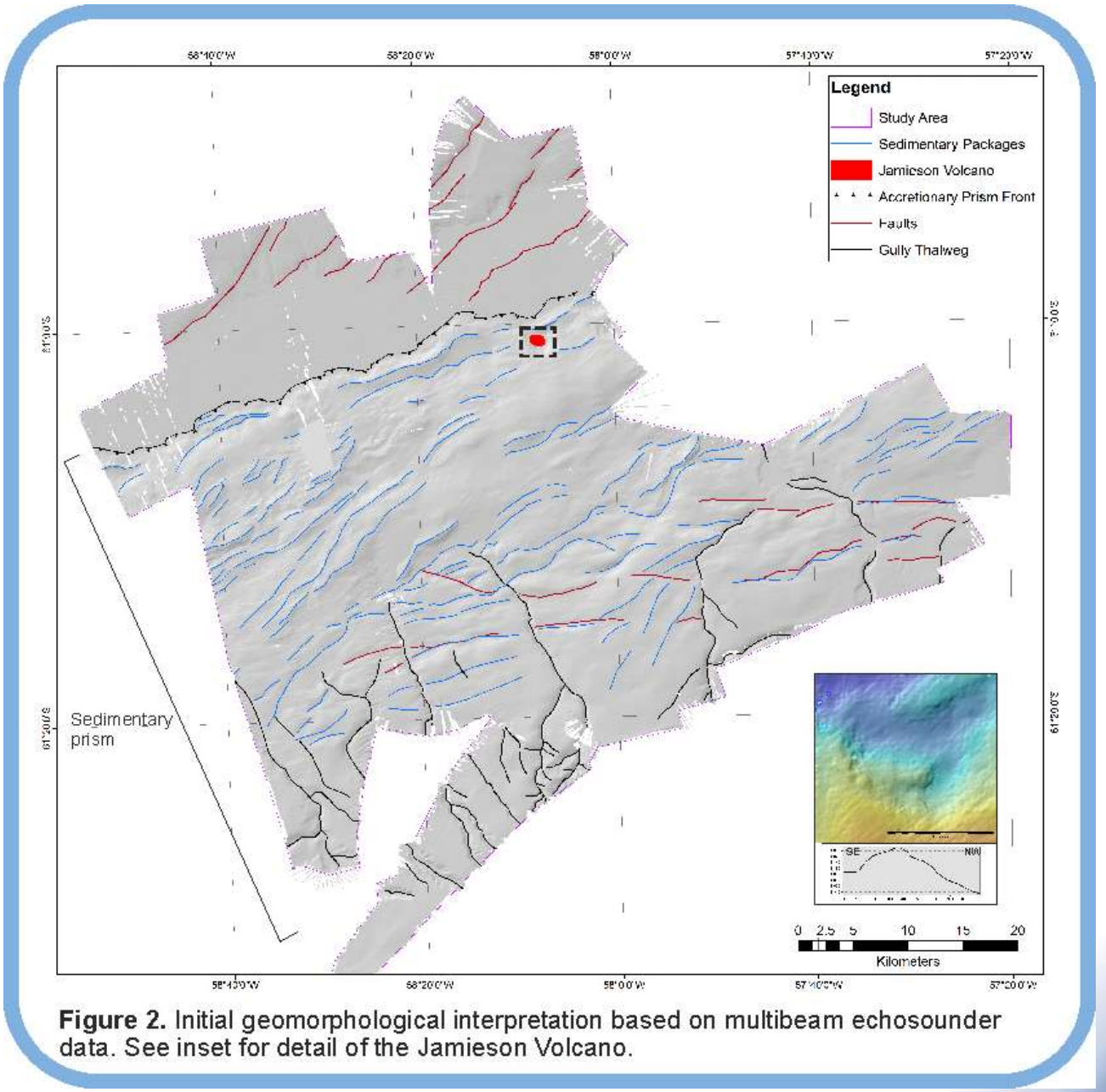
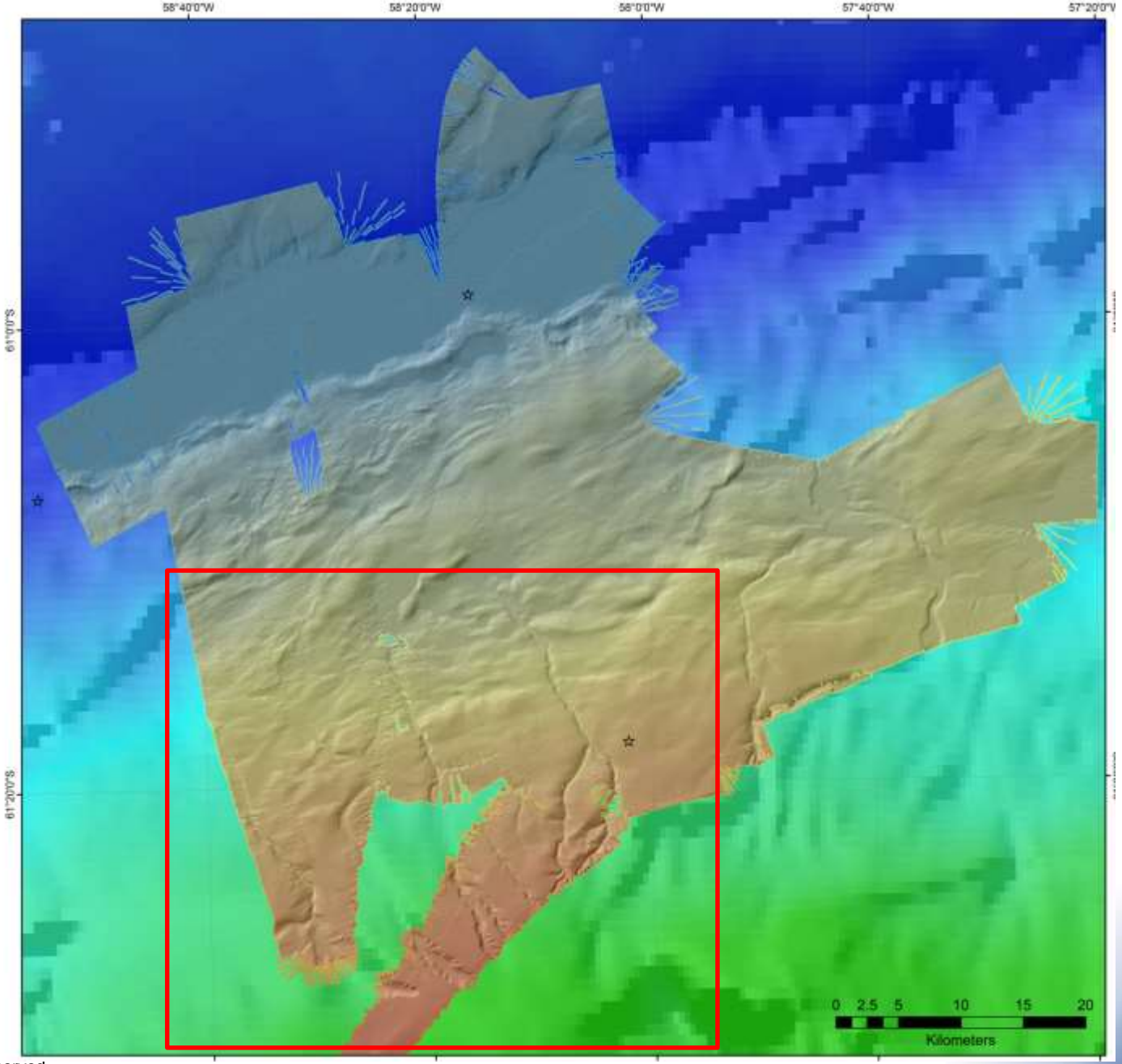
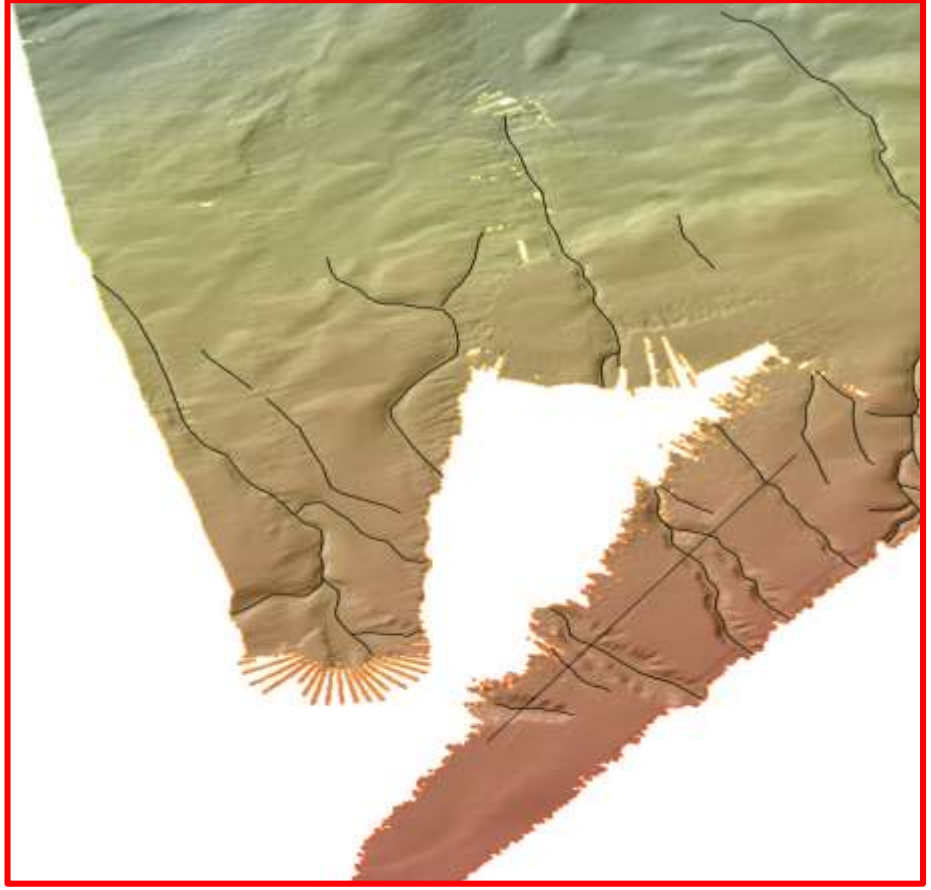


Figure 2. Initial geomorphological interpretation based on multibeam echosounder data. See inset for detail of the Jamieson Volcano.

South Shetland Trench. Stewart et al., in prep



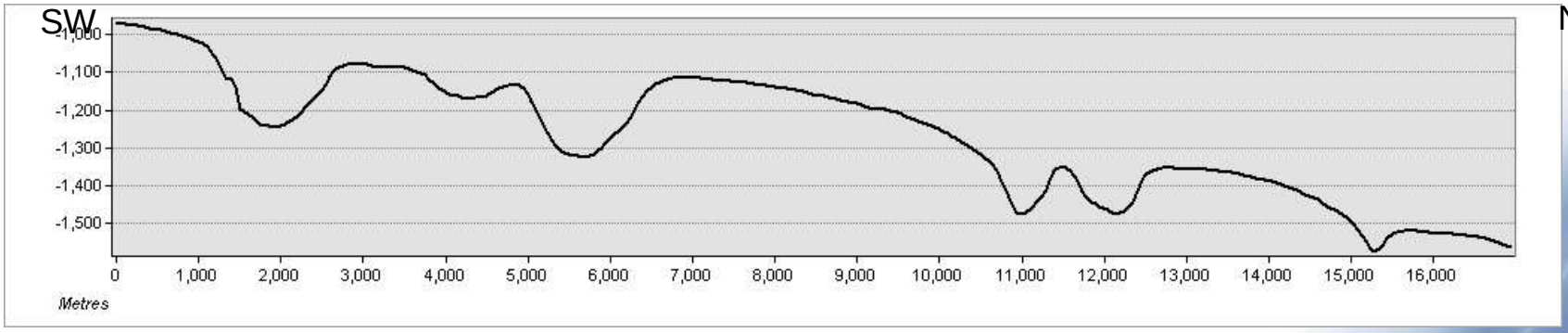


Found between ~450m and ~3600m water depth (probably extends further downslope).

11 individual gullies (and tributaries) imaged.

Maximum depths are ~250m below surrounding sea bed.

Slope angles within the gullies locally exceed 45°.

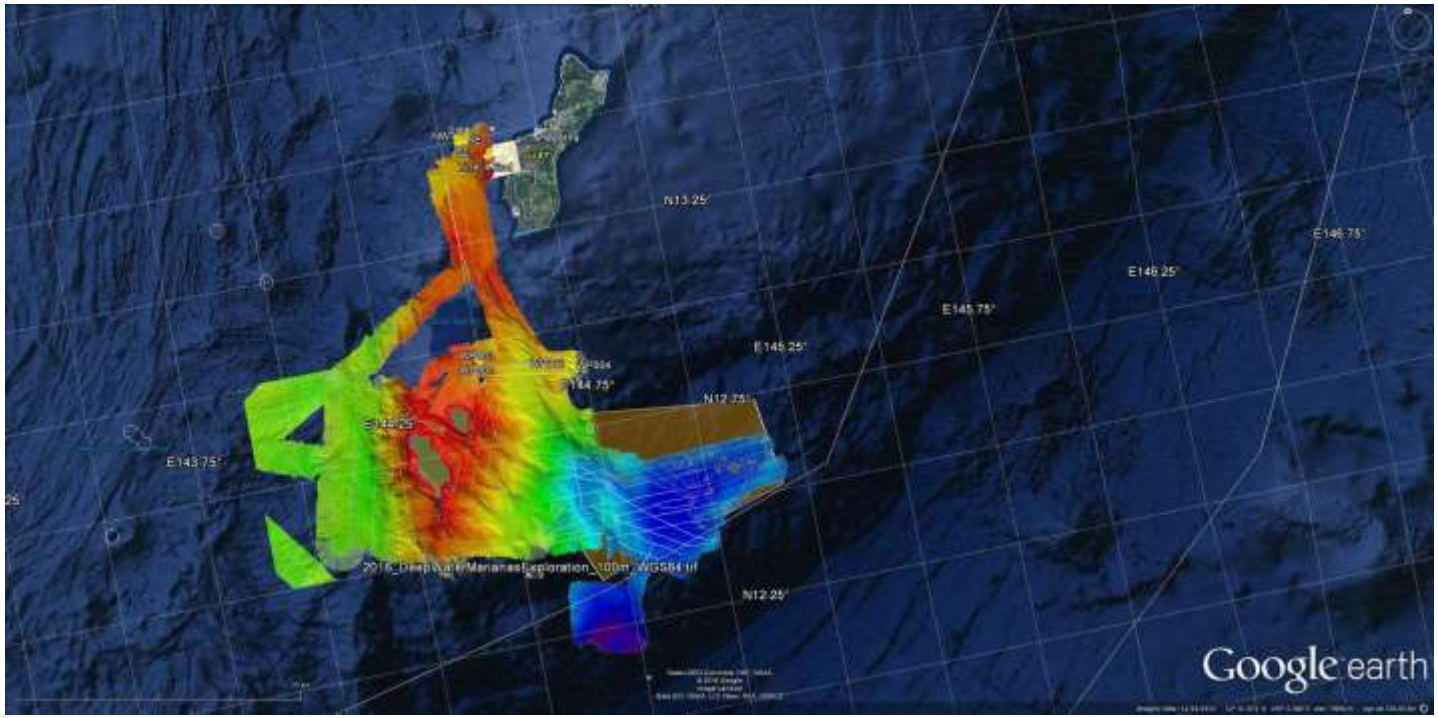


South Shetland Trench. Stewart et al., in prep

What about the deepest places on the planet?

Ocean trenches

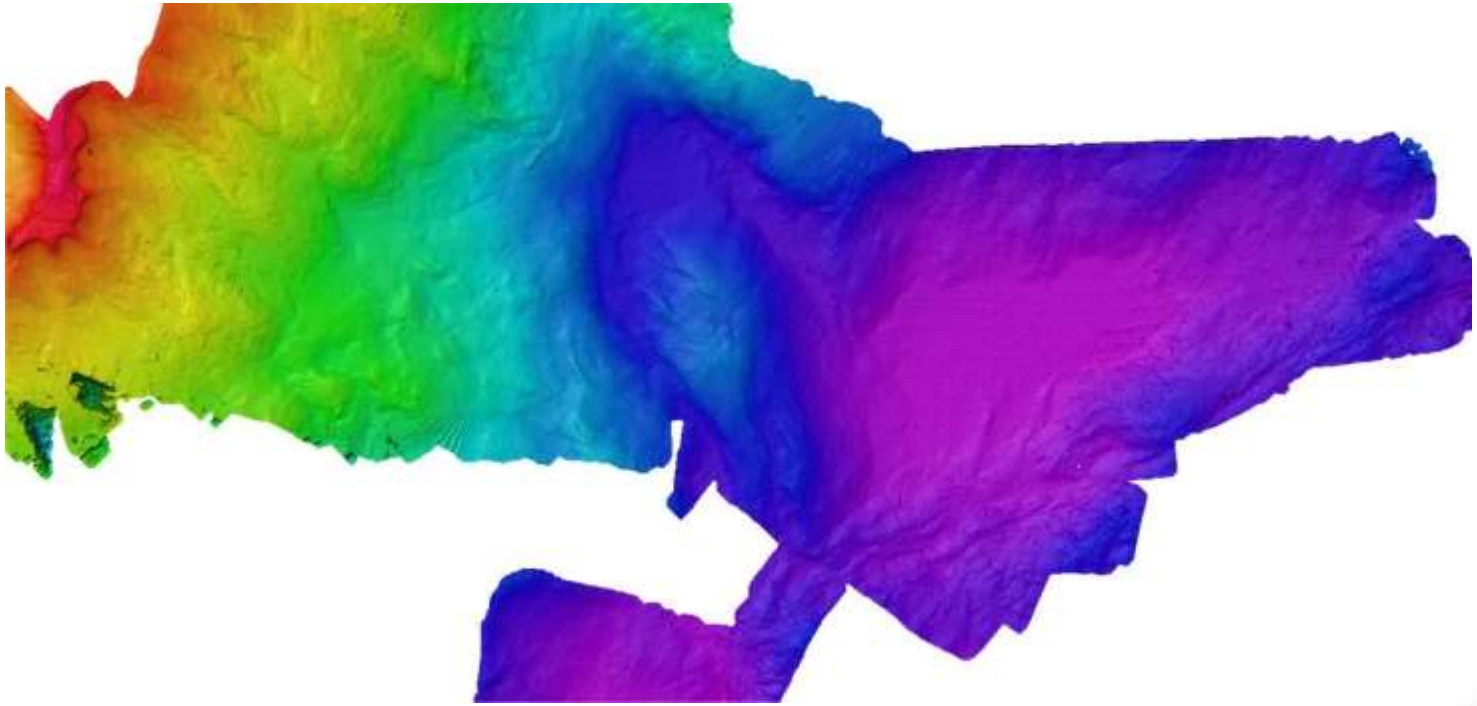
- 10m to 9000m water depth on edge of the Mariana Trench using EM302



SCHMIDT OCEAN INSTITUTE

Ocean trenches

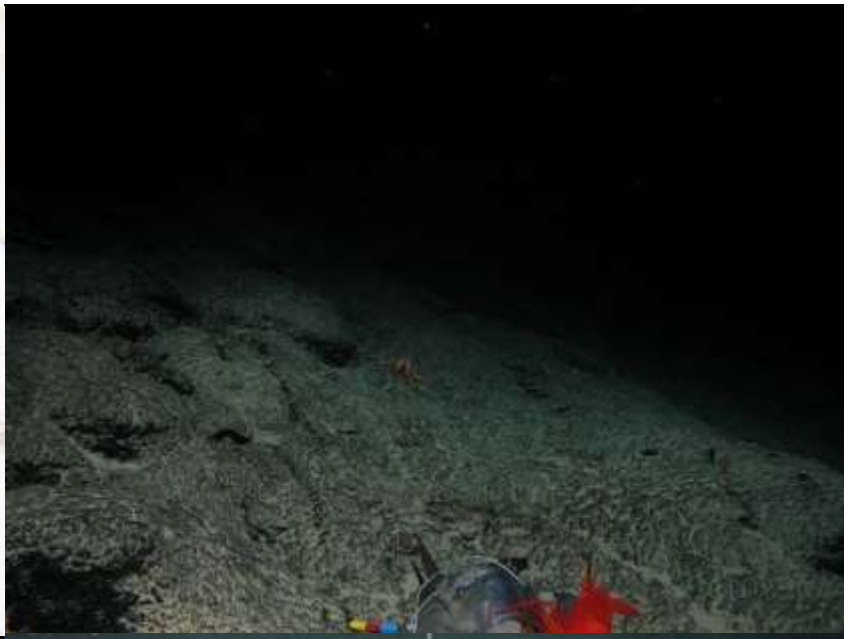
- 10m to 9000m water depth on edge of the Mariana Trench using EM302



Anything but homogenous…

SCHMIDT OCEAN INSTITUTE

Courtesy Alan J. Jamieson
Newcastle Univdersity

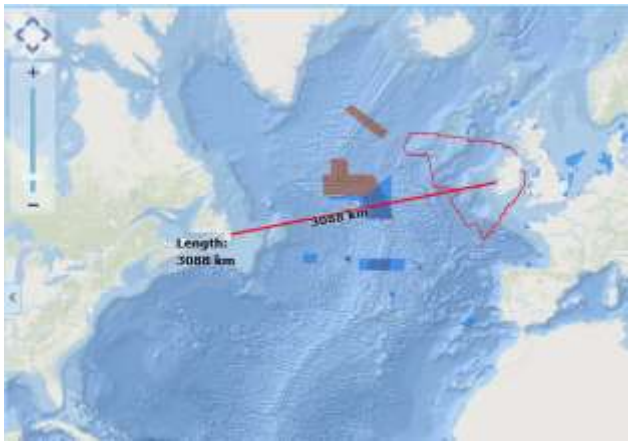


Farther afield

European Seas

- EMODnet 'Geology' one of seven projects (e.g. chemistry, seabed habitats) that assemble data and maps in European marine environment;
- EU commission led to meet 'Good Environmental Status' by 2020;
- £20m invested thus far…

Atlantic seabed mapping

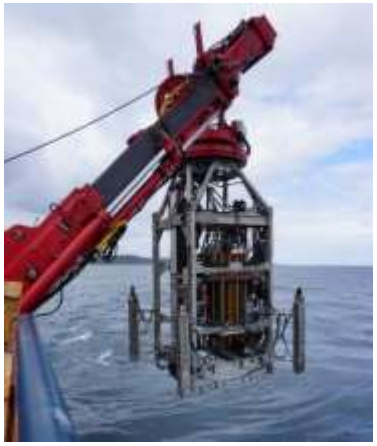


- Gov't requirement (EU, Canada, and US) for bathymetric map of N. Atlantic;
- Dataset to underpin other scientific disciplines as well as human and economic impacts (e.g. jobs);
  - Irish seabed mapping estimated return of 6-euros for every 1-euro spent on mapping;
- ~$80 million? Estimated cost to complete bathymetry mapping;

Survey and Sampling technologies

AUVs:

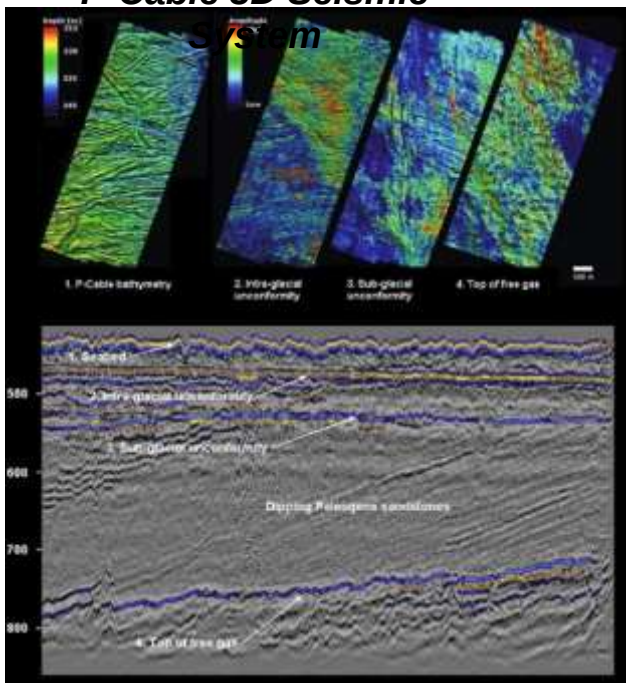
•Mulitple sensors;
•Stable platform – variable depths;
•Below-ice operations;
•Repeat surveys;
•Utilize ships of opportunity.



Seabed Drills:

•60-200 m penetration
•Mobile and compartmentalized;
•No drill ship (cost effective!)

P-Cable 3D Seismic System



High – resolution 3D seismic data:

•Image geomorphology at multiple sub-seabed horizons

Unmanned Surface Vessel (USV)

•Precision navigation;
•Multiple sensors;
•Less staff cost.

Challenges and conclusions…

- Must be multidisciplinary and cross border to pool resources.
- Applied mapping methods range from classical (manual) through to automated techniques.
- Sampling techniques need to be examined. Cost efficient and rapid.
- Challenges include: different scales and users, standardizing approaches, and map outputs (e.g. not just a flat map), sharing of data/expertise across sectors, borders.

- No ‘one size fit’s all’ approach
  - Different objectives require suitable methods.
- Improved image-based and mathematical/computational methods improving efficiency, removing user bias.
- Still requirement for geological expertise - for accurate, and more nuanced characterization of seabed and shallow sub-seabed environment.
- Adopt, and adapt to technological advance (e.g. R&D institutes and industry).

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