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University of Southampton

Continental Shelf Environments: Seabed Exploitation Options and Approaches

by

Dr. Justin Dix

The LRET Research Collegium
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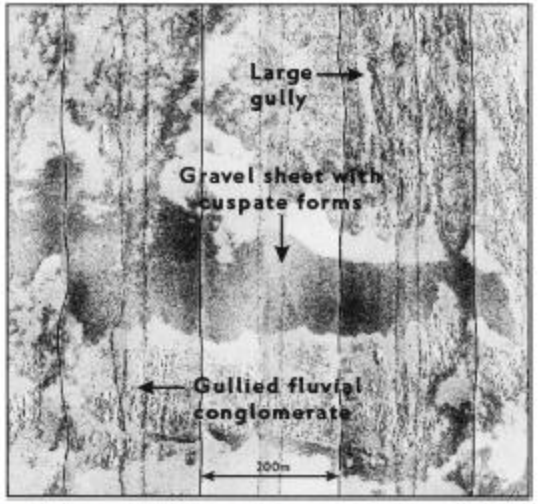
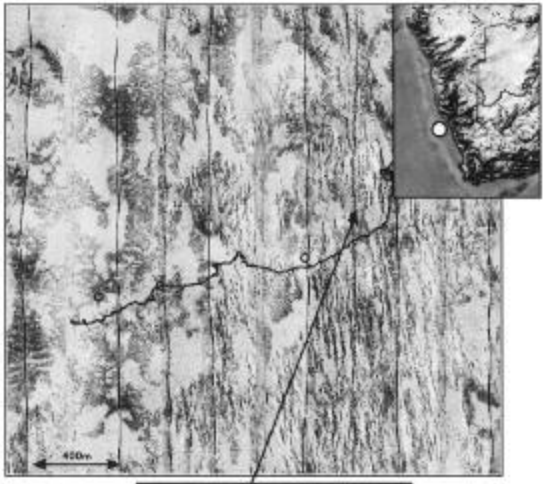
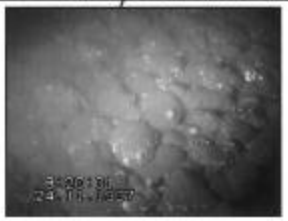
Offshore Diamond Mining

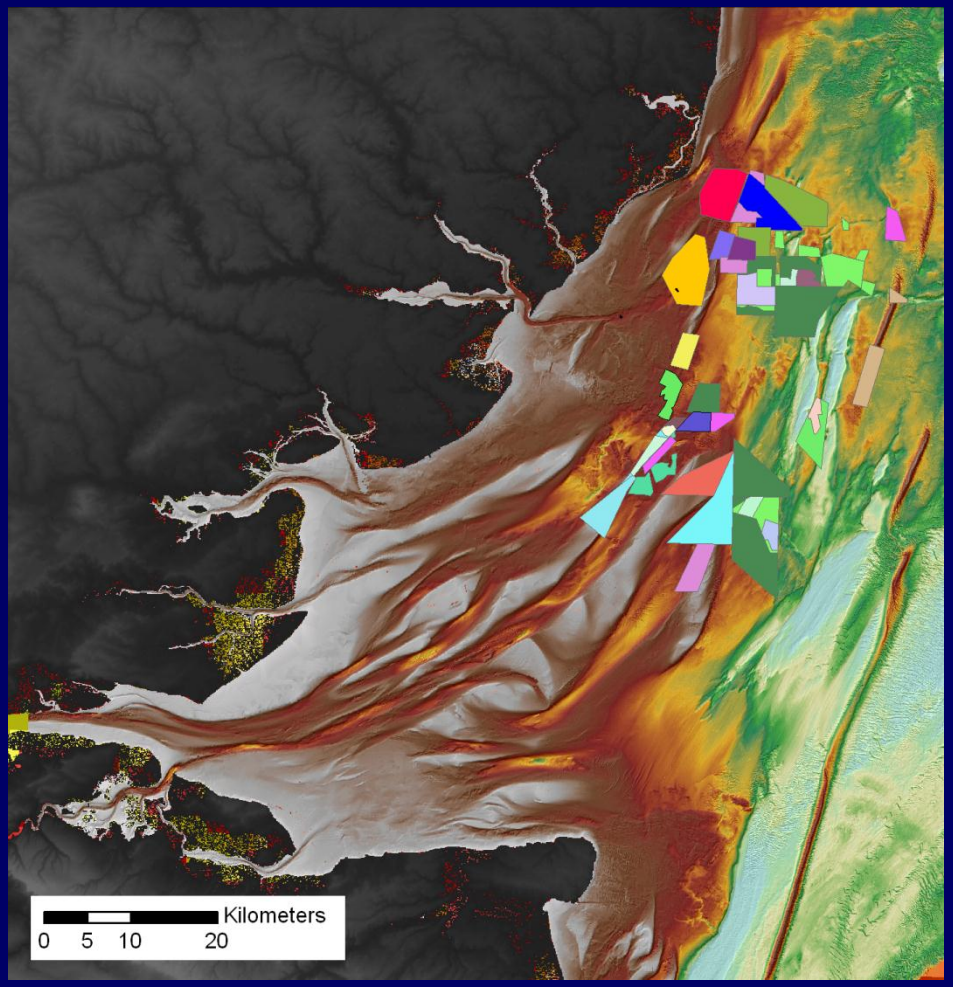
- De Beers has led the way in offshore diamond mining on the West Coast of Africa associated with the offshore deposits of the drainage basins (particularly the Orange River) of the Kaapvaal Craton.
- Deposits associated with the Pleistocene-Holocene aeolian/fluvial/marine deposits along the submerged shelf.
- Exploration extensively by ROV and AUV mounted sonar systems.
- Due to extensive weathering only most robust diamonds tend to survive such that marine diamonds have a very high ratio of gem quality diamonds (up to 95%)
- Still major source of supply in 2011 Namdeb Holdings (50/50 Joint Venture between Nambian Government/De Beers) extracted 990000 carats from their marine activities.



Corbett & Burrell, 2001



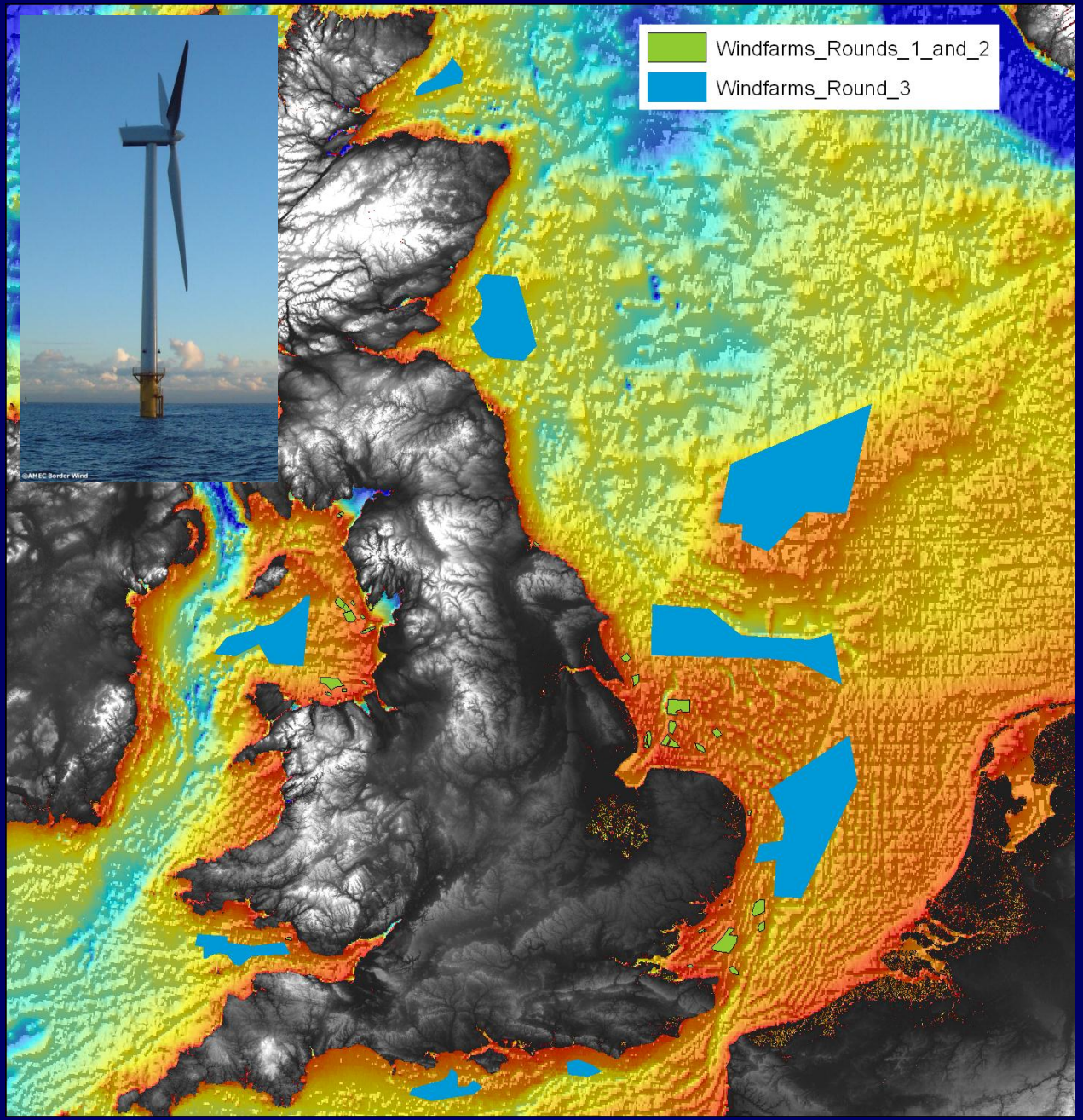




Offshore Aggregate Mining

- Aggregates are mixtures of sands, gravel and crushed rock/other bulk mineral used for construction (principally as a component of concrete) and in civil engineering.
- Approximately 20% of sand and gravel used in England and Wales is supplied by the marine aggregates industry.
- In south-east England this represents 33% of sand and gravel for construction.
- Currently 70 production licenses exist which accounts for 21 millon tonnes per annum.
- These licenses only cover 0.12% of UK continental shelf and of this only c. 8% per annum (105 km^2 in 2010).
- Main areas: Humber, East Coast, Thames Estuary, Eastern English Channel, South West and North West.

UK Offshore Wind

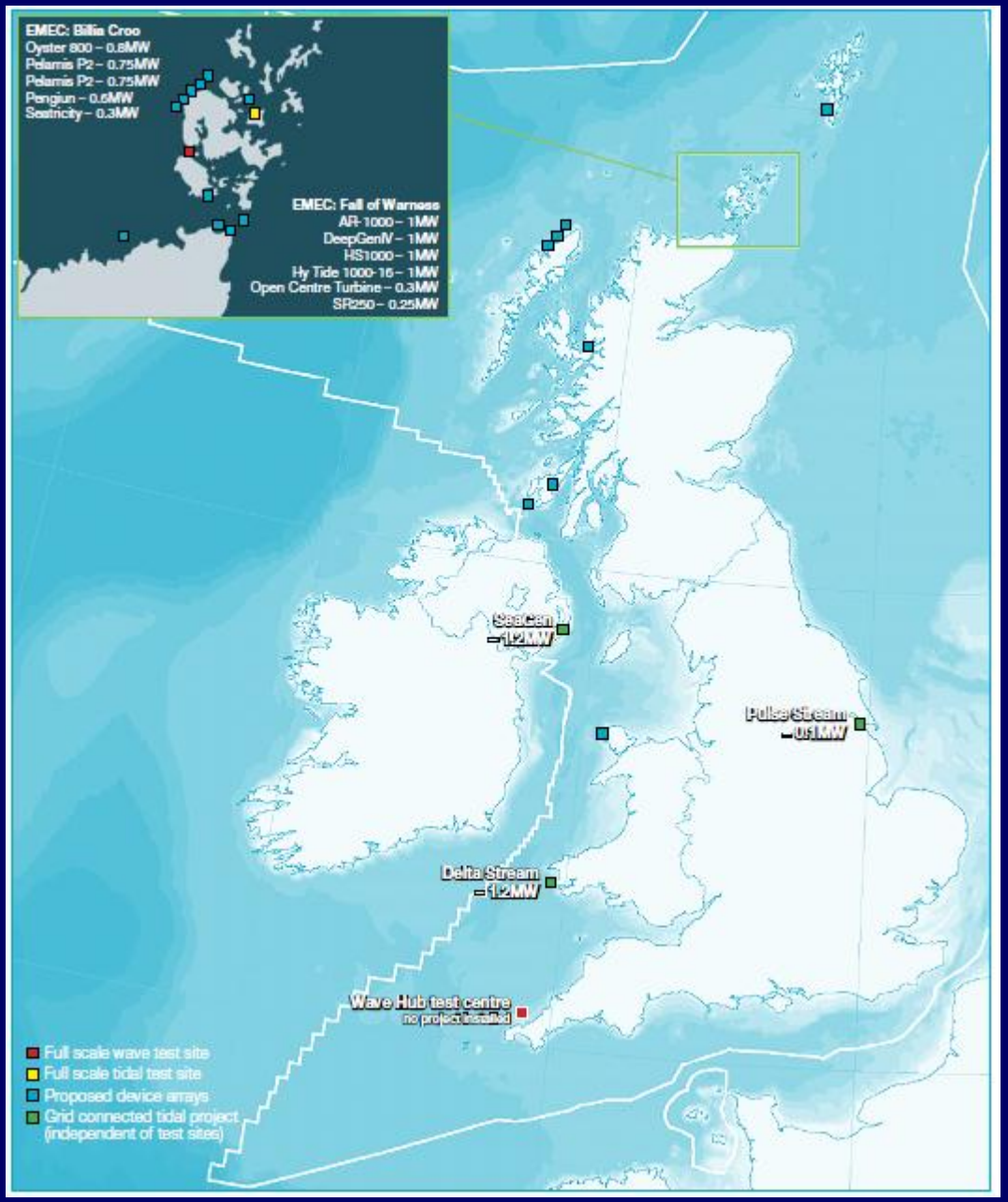


- First near shore project in Blyth Harbour in 2001. Largest current windfarm is Thanet (300 MW); largest in construction is London Array (1 GW projected)
- There should be 8 GW of capacity by 2016; 18 GW by 2020.
- Currently provides 1.5% of UK electricity production; growing to 7-8% by 2016 and c. 17% by 2020.
- 15 Operational windfarms; 7 in construction and 6 with planning consent.
- There are a further 40 GW of projects with leases and at various stages of the pre-planning consents.
- In 2007 employed 700 FTE's increasing to 3200 FTE's in 2011. Projections suggest by 2020 31 GW will create 42,400 direct FTE's and 25,300 indirect FTE's.

RenewableUK 2012: Trade and Professional Body for UK wind and marine renewables

UK Wave & Tidal Power

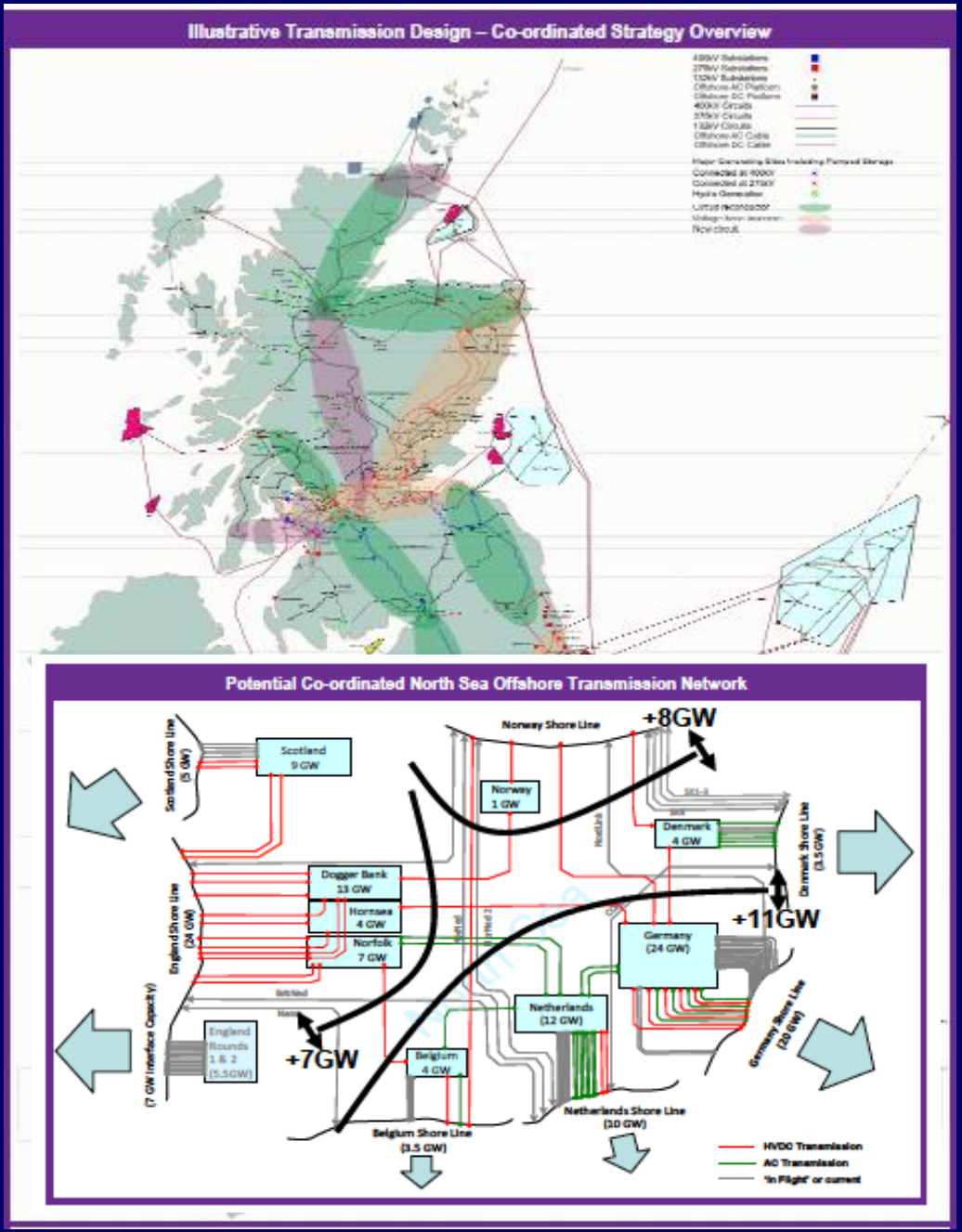
- Significantly less developed with only 5.6MW grid connected power recorded in 2011.
- In 2012 another four devices aim to be connected at EMEC (European Marine Energy Centre) giving an approximate doubling of power to > 11 MW.
- DECC's target is for 300 MW by 2020 whereas the industry is aiming for 1.6 GW




Pelamis P2


Deep Gen IV

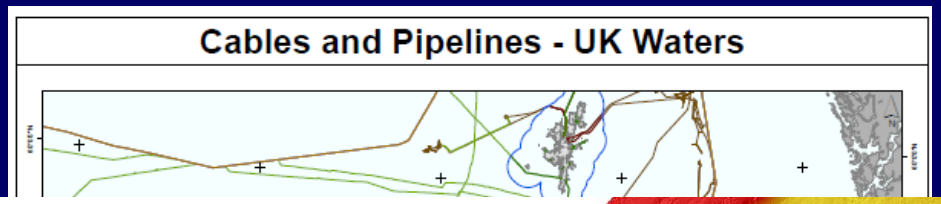
RenewableUK 2012: Trade and Professional Body for UK wind and marine renewables



UK Cable Routes

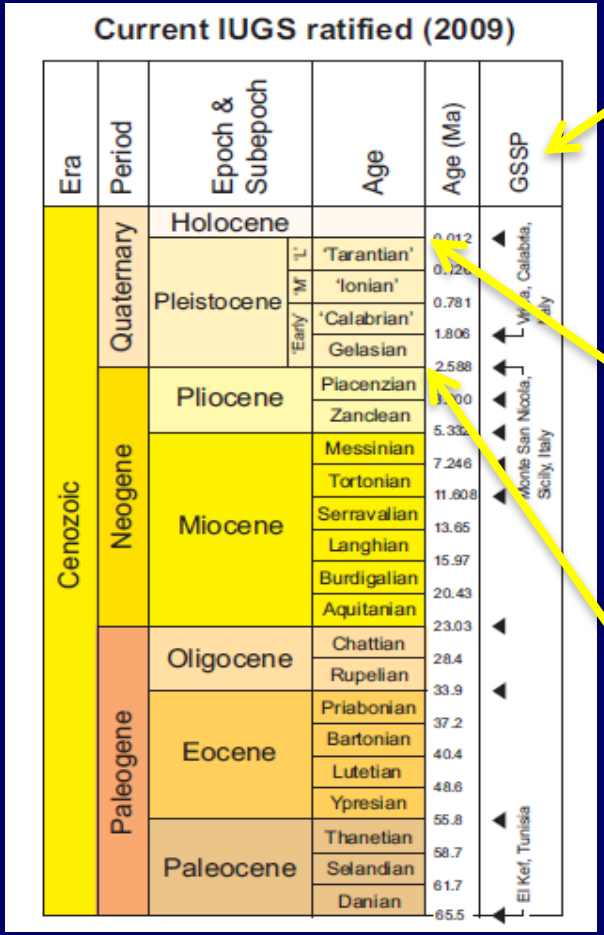
- With up to 95 % of overseas internet and telephone traffic supported by undersea fibre optic cables, they are an important part of our national infrastructure. As a key landing station between Europe and North America, the UK play a vital role in international communications
- Similarly there has been a huge increase in the demand for subsea HV cable systems:
  - For connection of offshore renewable energy generation
  - For the creation of a European SuperGrid
- A single one of these routes alone has an installation budget of £1 Billion

UK Pipelines



• Pipelines act as conduits from offshore oil and gas fields to shore and their distribution thus follows the location of reserves and

International Commission on Stratigraphy: Sub-commission on Quaternary Stratigraphy and the International Union for Quaternary Research 2009 Timescale



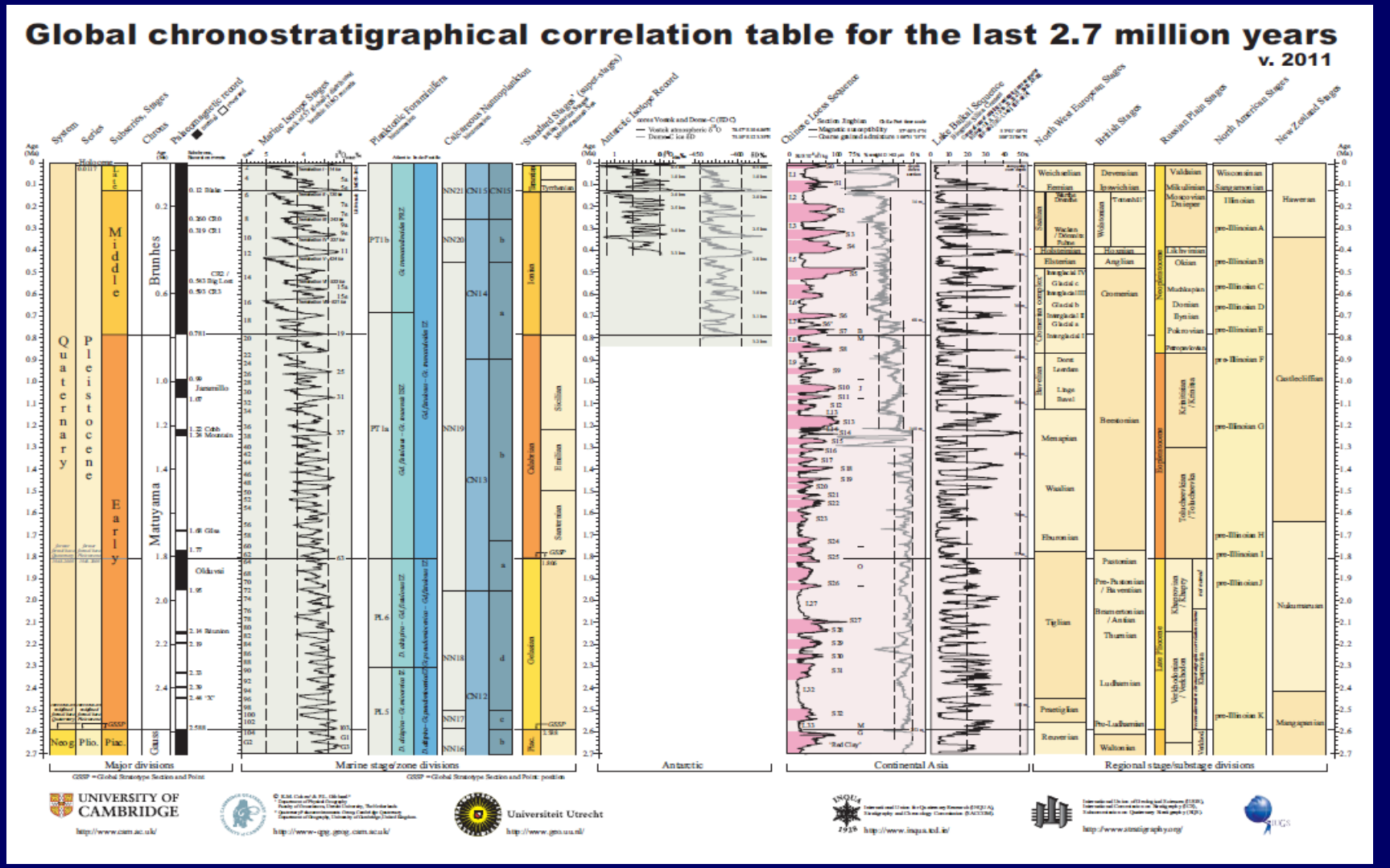
Global Stratotype
Section and Point

Holocene – Pleistocene boundary
Defined from the NorthGRIP Greenland
Ice core (based on fist signs of climatic warming
@ 11700 calendar years b2k (before AD2000)
Walker et al., 2009
Note Flandrian used as first and only stage of
the Holocene in the British Isles

Base of Quaternary,
Pleistocene Epoch and
the Gelasian stage
defined at 2.588 Ma from
Section at Monte San Nicola, Sicily
Gibbard et al., 2010

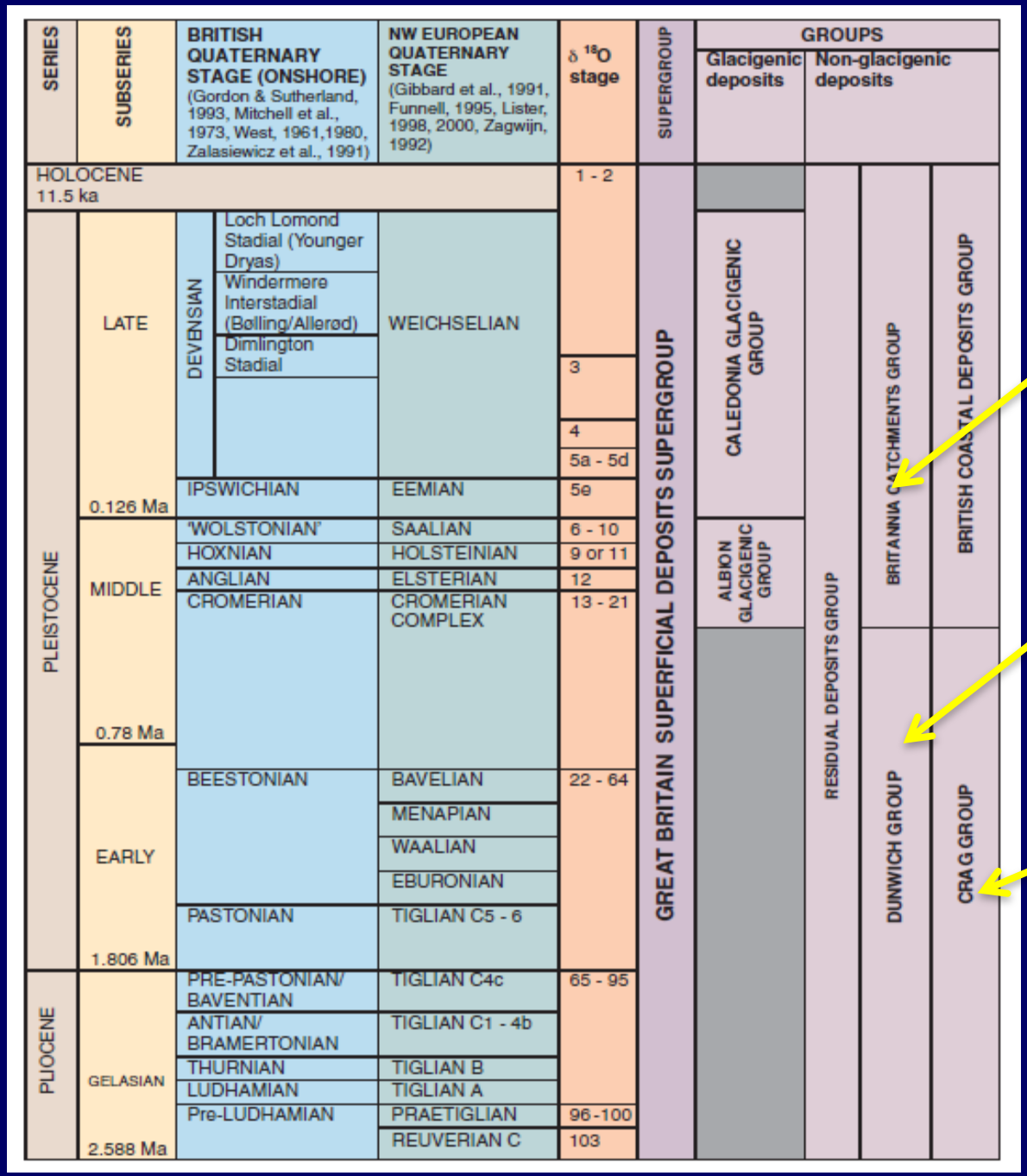
Gibbard et al., 2010
http://www.quaternary.stratigraphy.org.uk/

Pleistocene Sub-divisions



http://www.quaternary.stratigraphy.org.uk/

Lithostratigraphical Framework

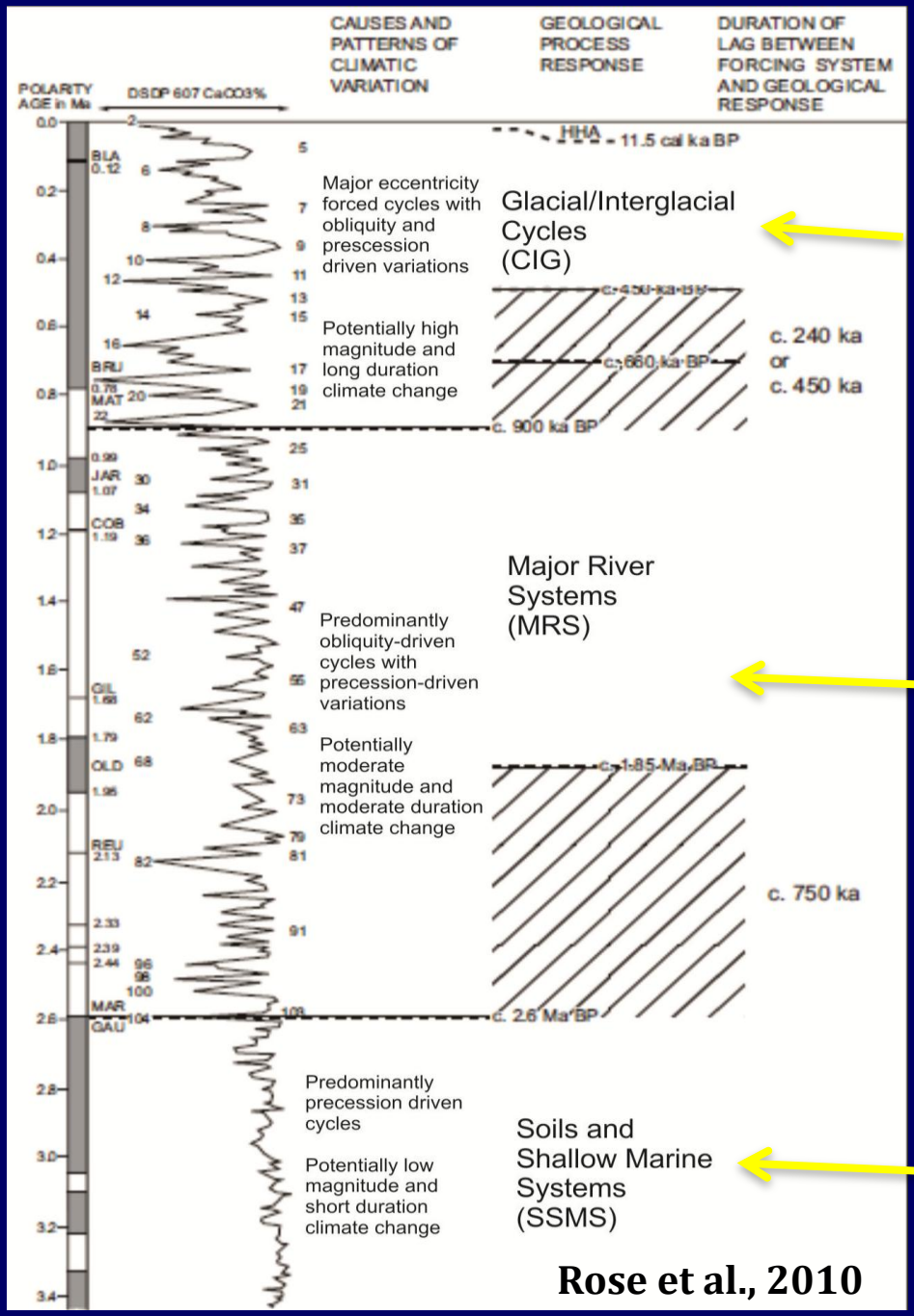


Britannia Catchment Group:
Non glacigenic deposits (fluvial, Lacustrine and aeolian Post-Cromerian deposits

Dunwich Group: mainly Fluvial sands and gravels formed in Pre-Anglian times Early Pleistocene

Crag Group: mainly Marine deposits formed in Pre-Anglian times Early Pleistocene

McMillan, 2005
McMillan et al., 2005



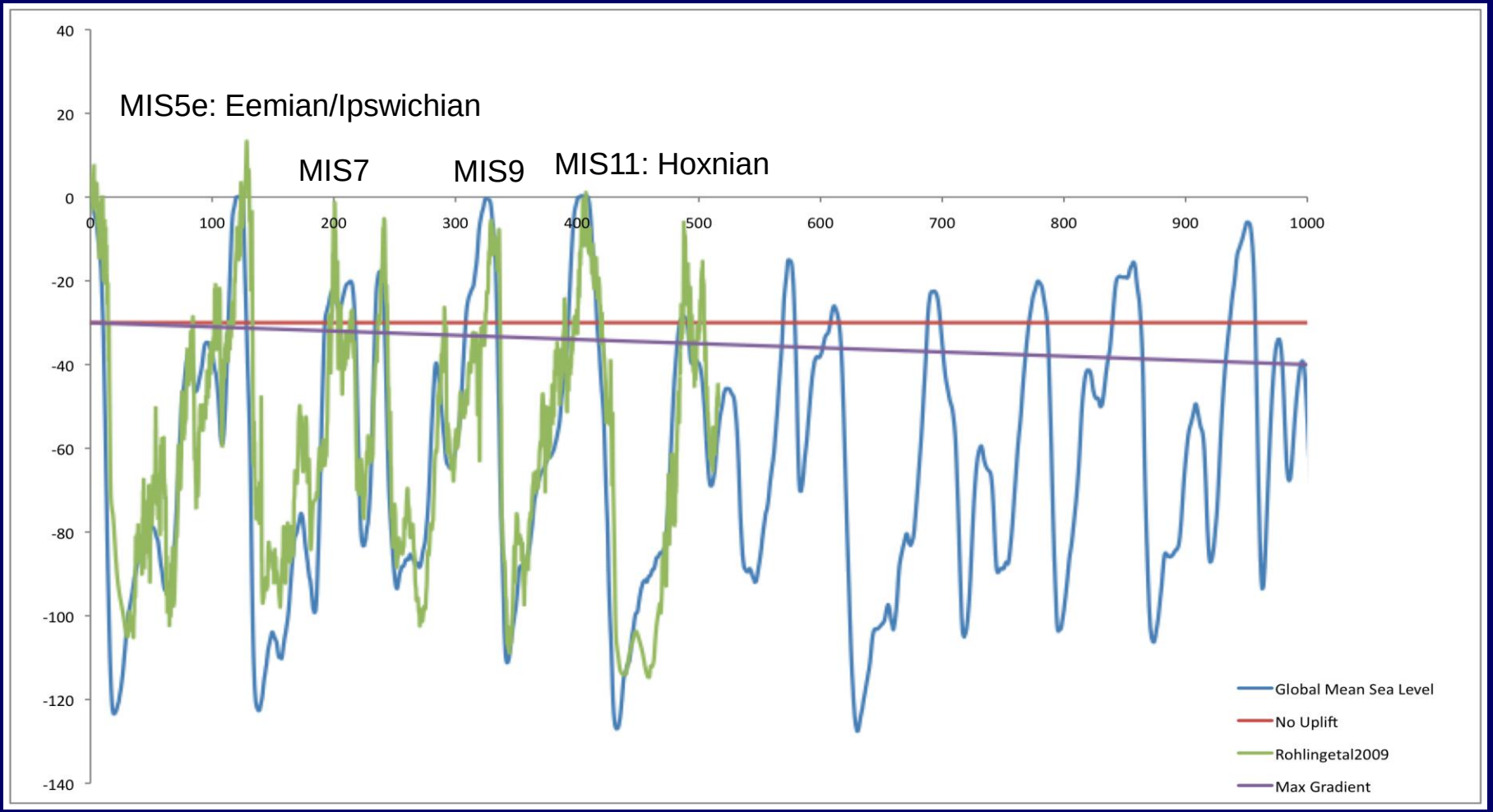
Rose et al., 2010

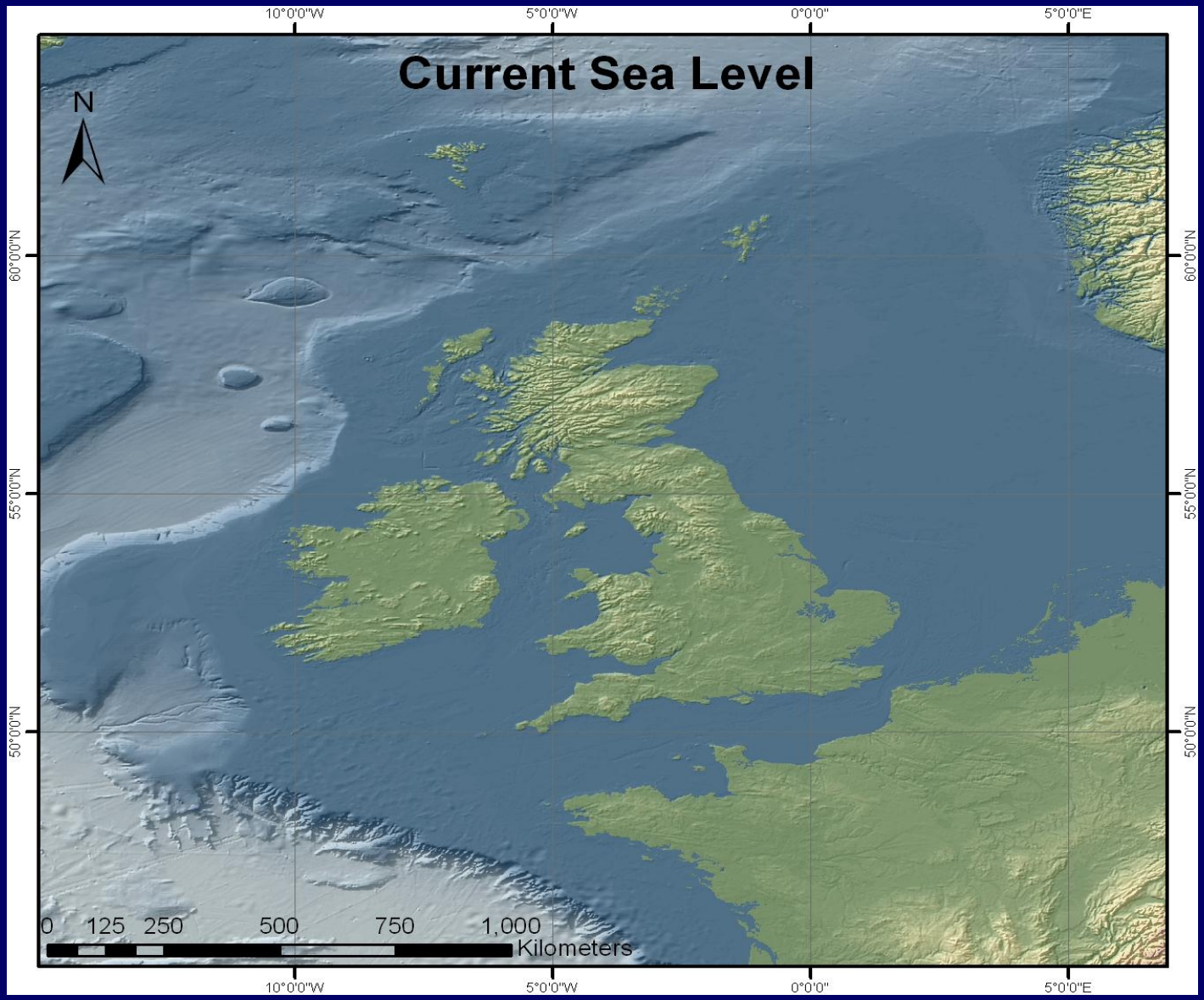
Highly variable and fragmentary deposits but extensive Throughout midland, eastern and Northern England, Wales, Scotland, Ireland and adjacent seas. Deposits include Direct glacial material; glaciofluvial sands and gravels; Glaciolacustrine; fluvial deposits smaller and do not link to North Sea delta; aeolian loess deposits; raised beach deposits Glacial isostasy important syn and post major glaciations

Wroxham Crag in East Anglia and fluvial sands, gravels And silts associated with major river systems of Thames, Bytham, Ancaster, Solent and Mathon Rivers: Fluvial activity throughout Britain with coastal activity in Eastern Anglia. Rivers higher energy than SSMS and so strong physical erosion and potential hinterland glacier Systems. Rivers connected to North Sea Delta system.

Red and Norwich Crags in East Anglia and fragments elsewhere in UK: Extensive chemical weathering, low-energy river systems and coastal geomorphic domains with high energy wave and tidal current coastal systems associated with high global sea-levels. Rivers connected to North Sea Delta system. Tectonics important – net subsidence towards centre of offshore basins

Mean Sea level Equivalent Records (Eustatic) - Bintanja & Van de Wal, 2008 and Rohling et al., 2009




Current Sea Level
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0
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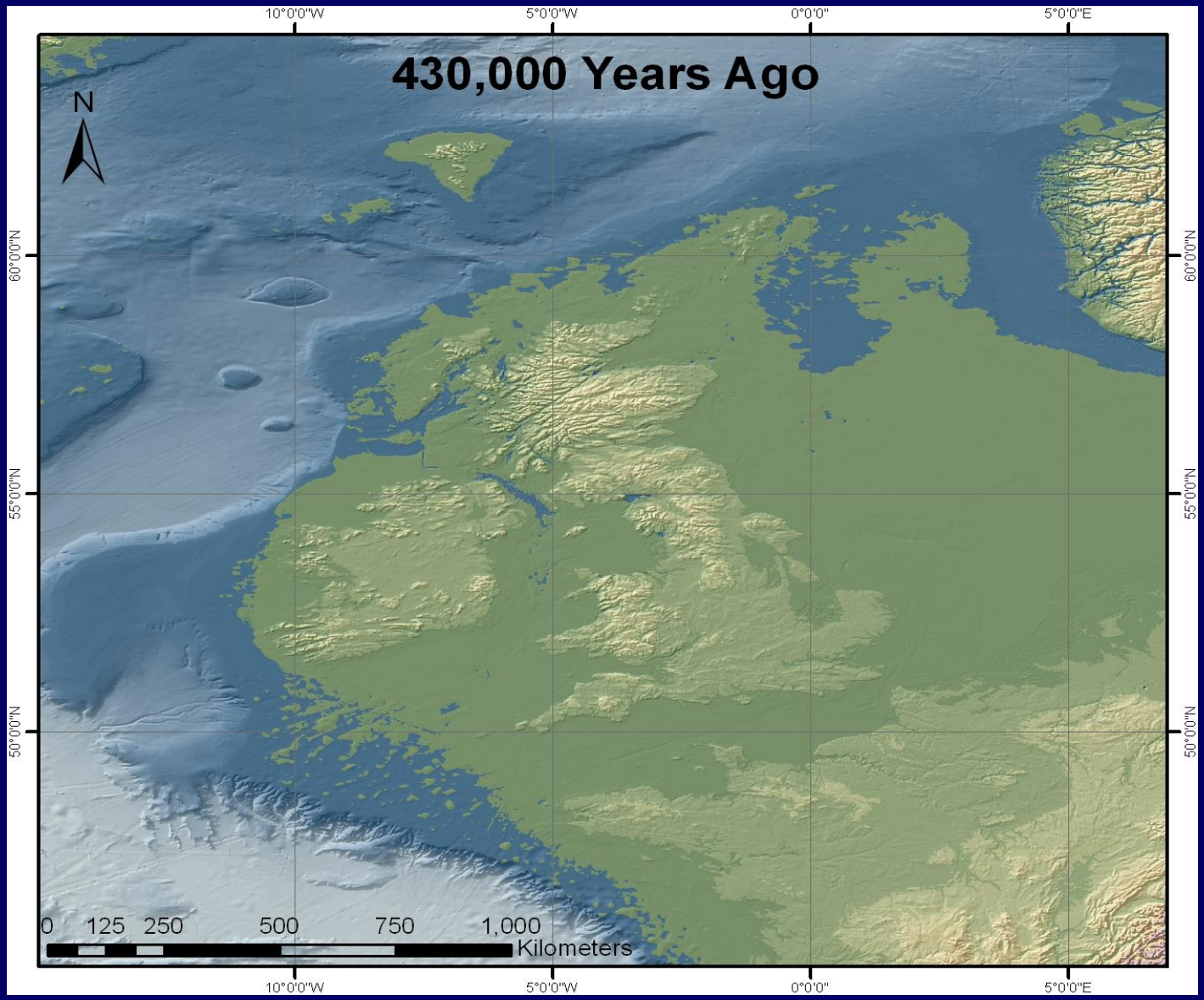
750
1,000
Kilometers


430,000 Years Ago
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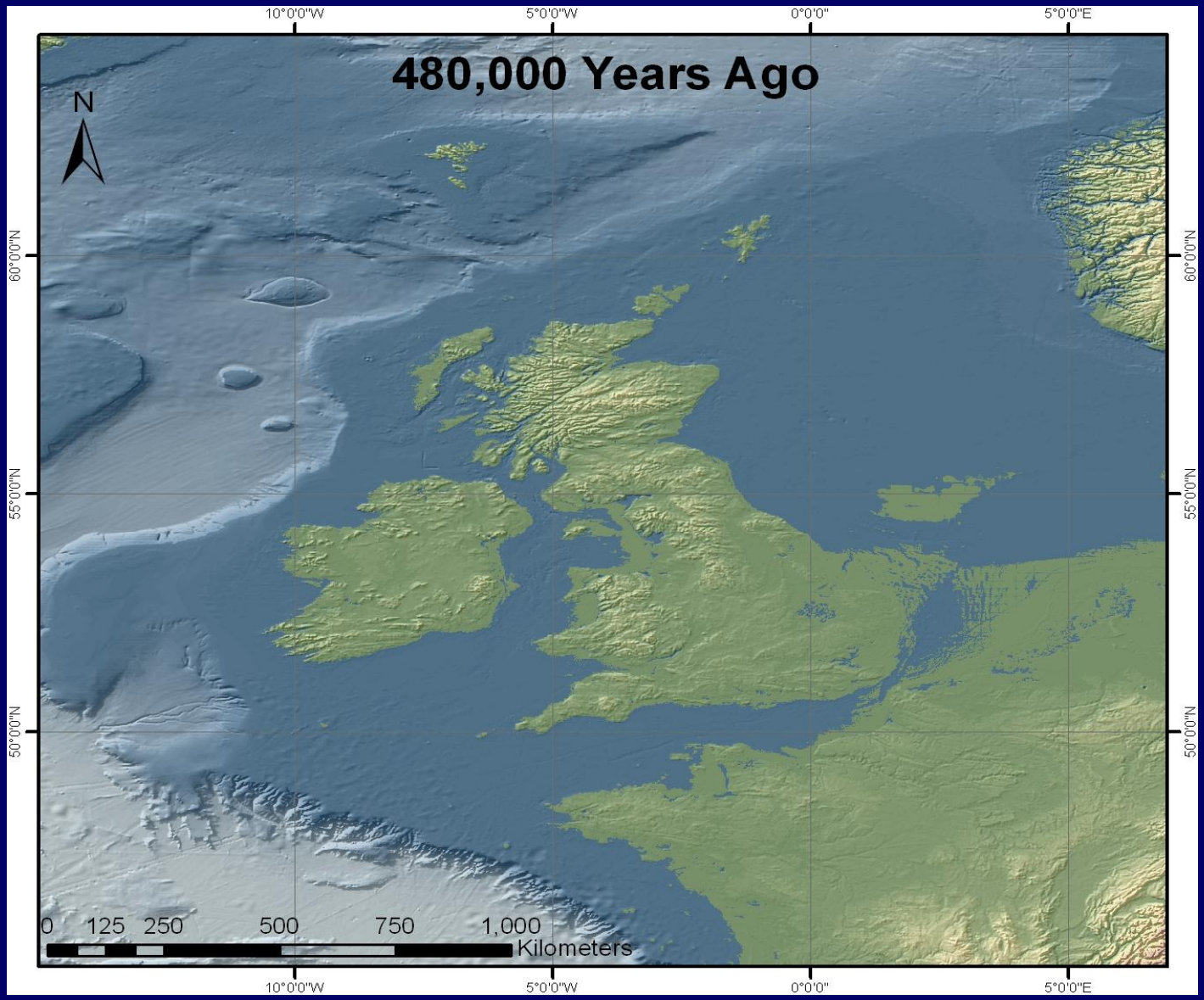
Kilometers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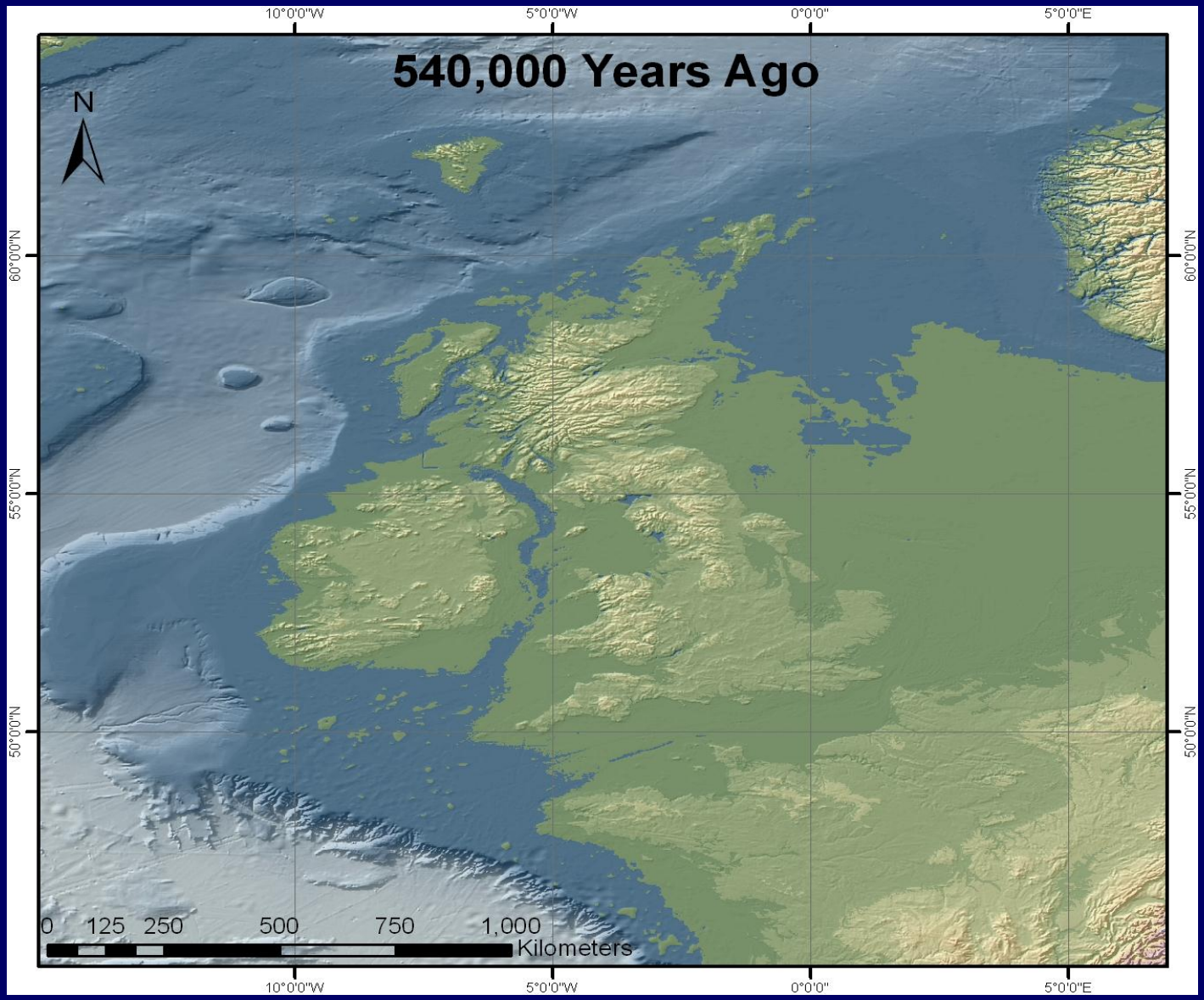
Kilometers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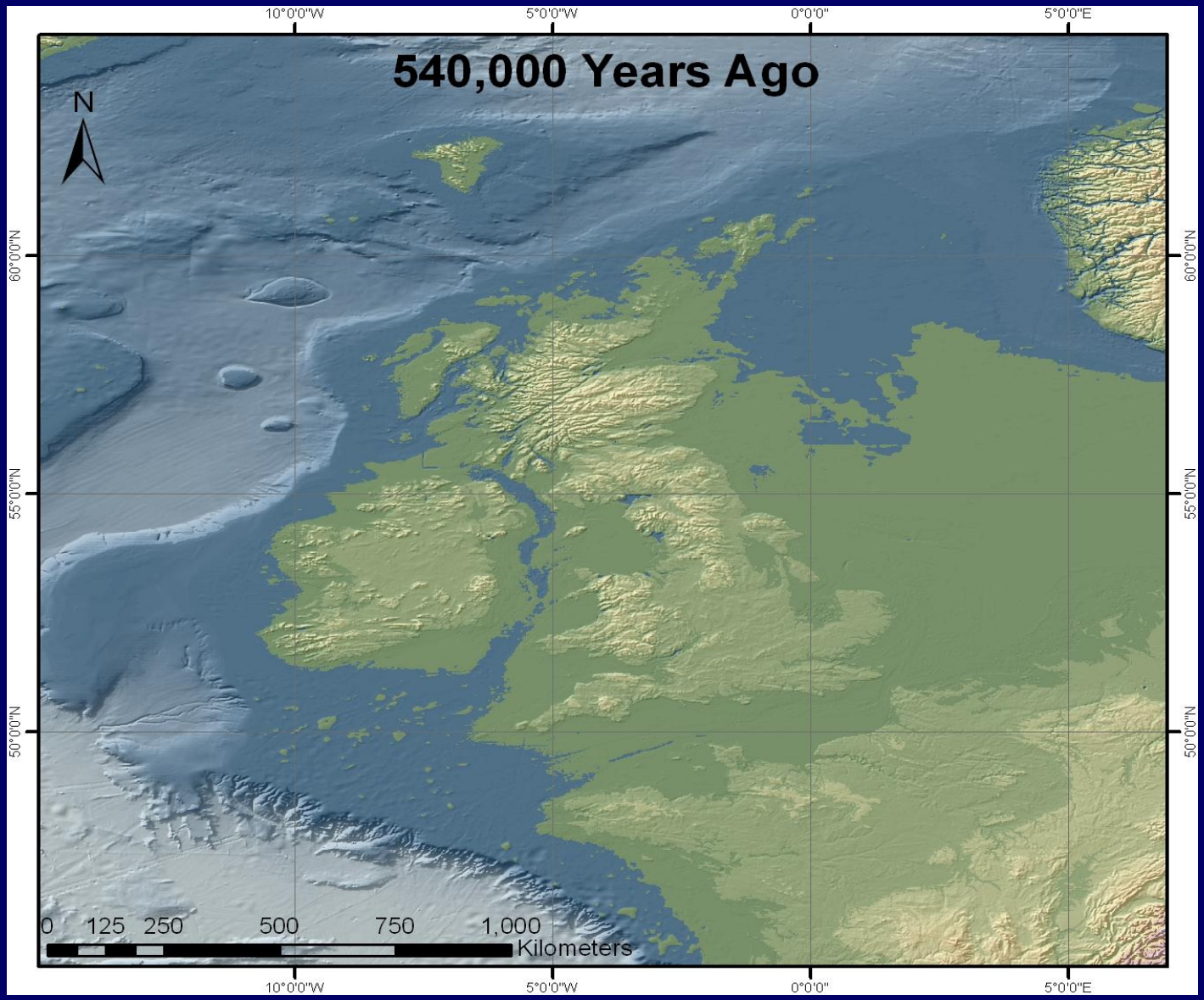
Kilometers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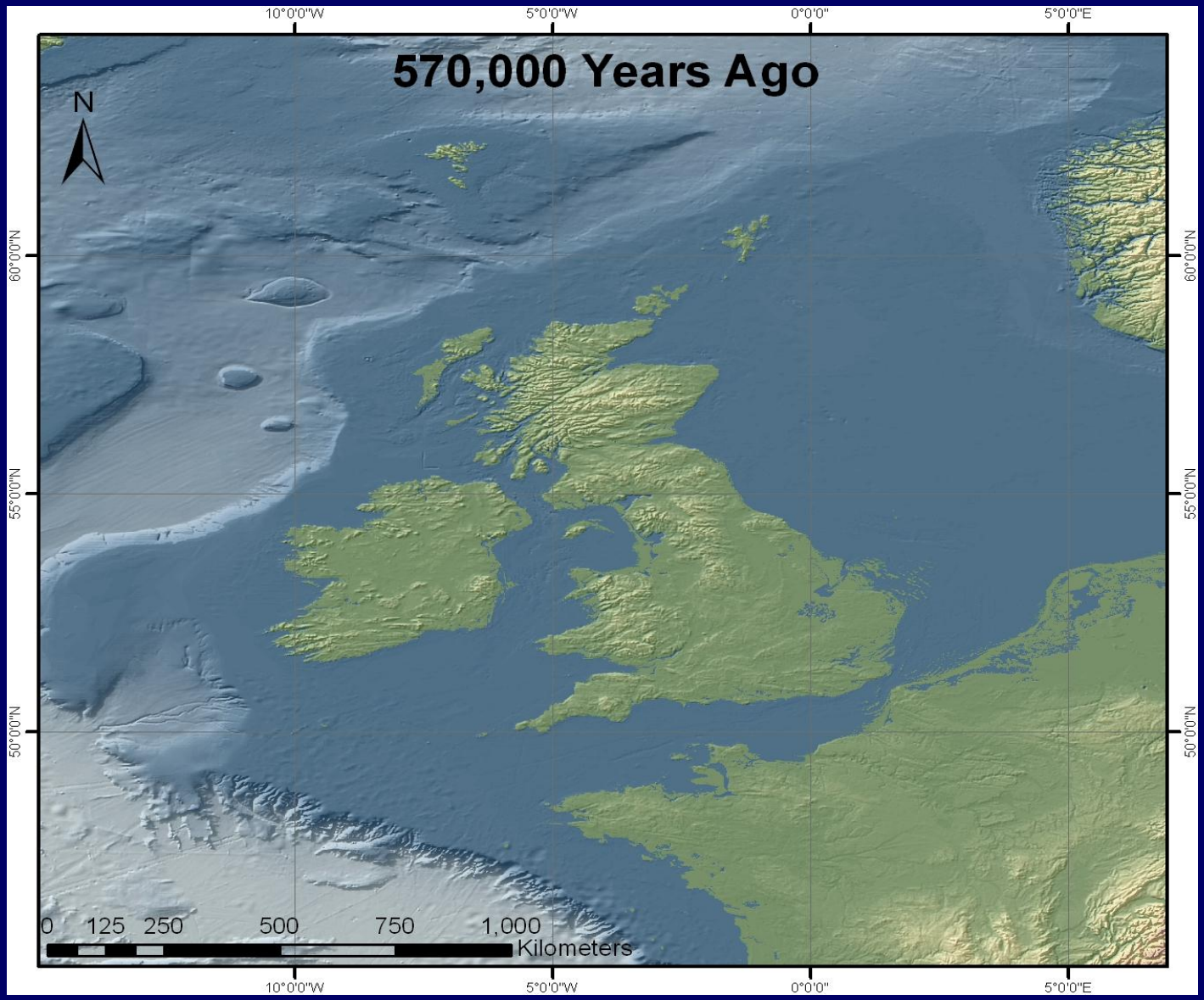
570,000 Years Ago
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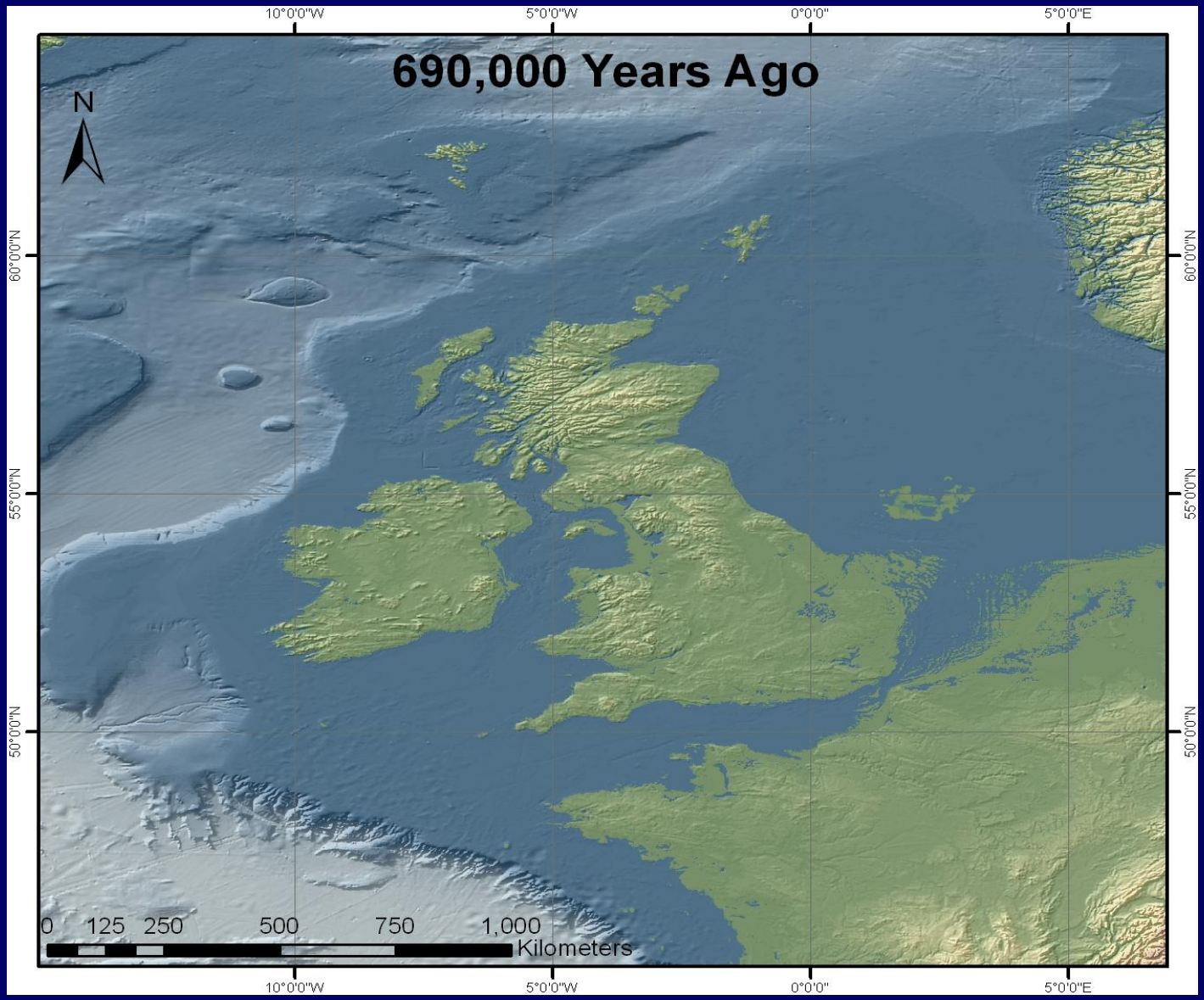
Kilometers


690,000 Years Ago
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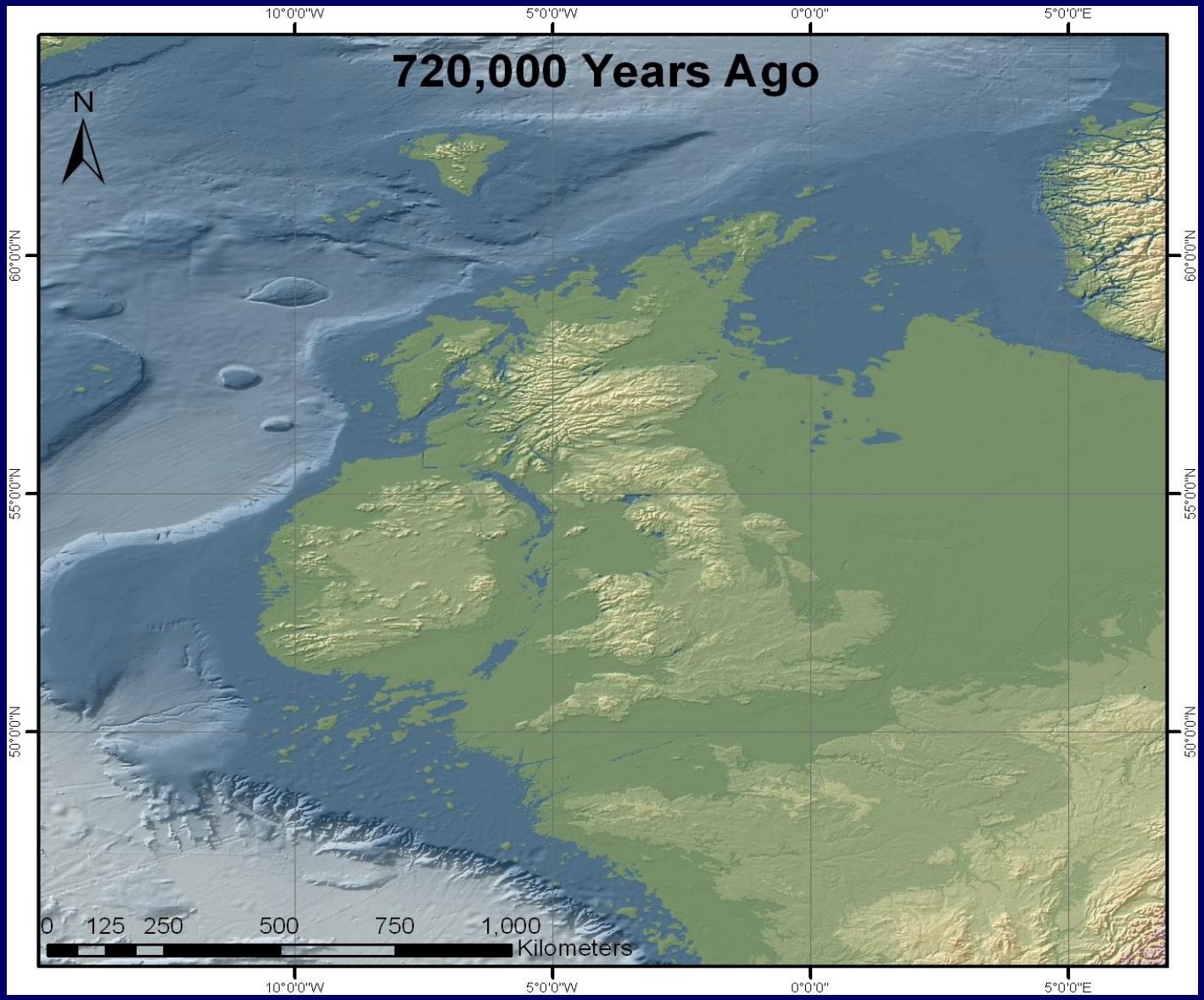
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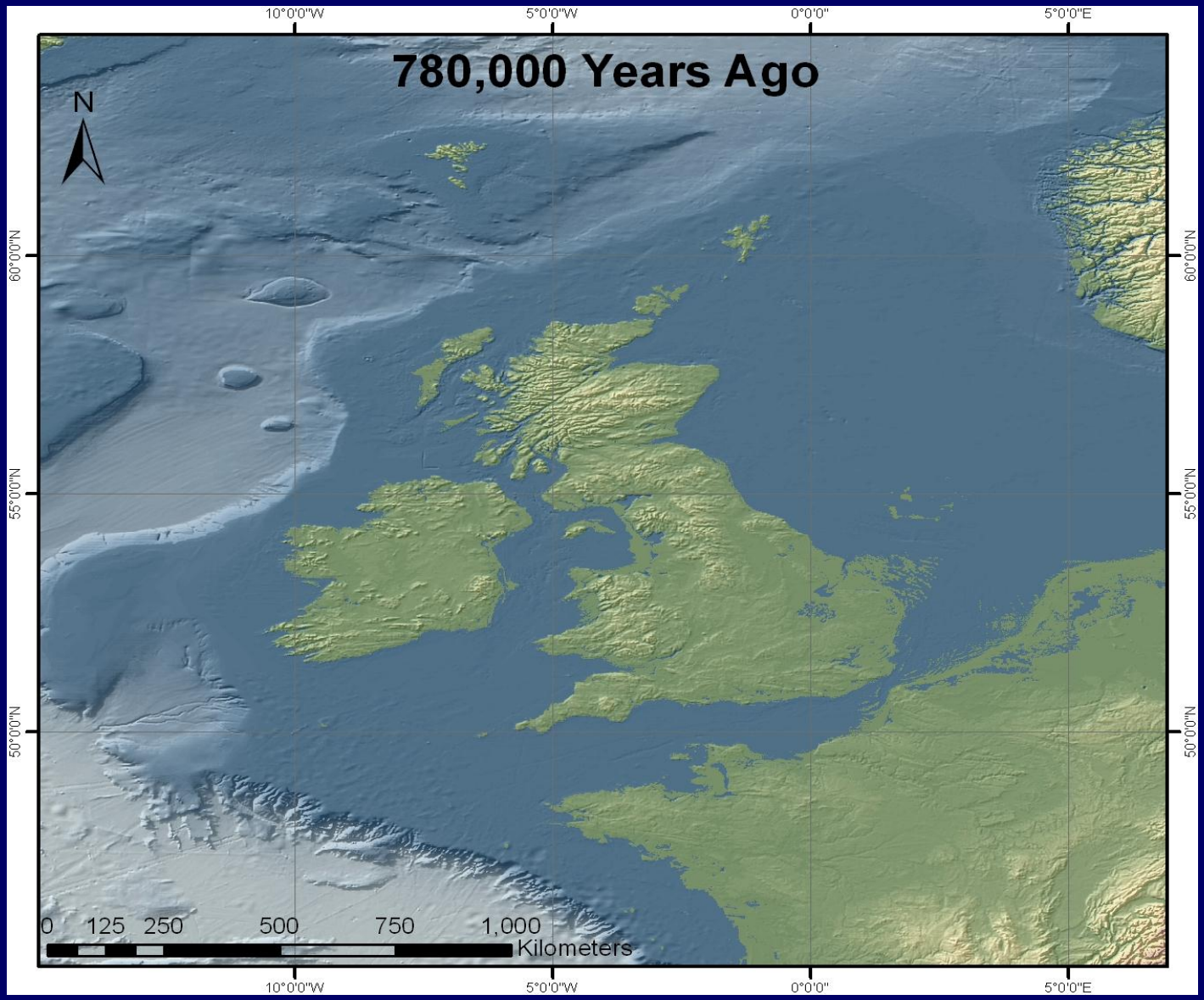
Kilometers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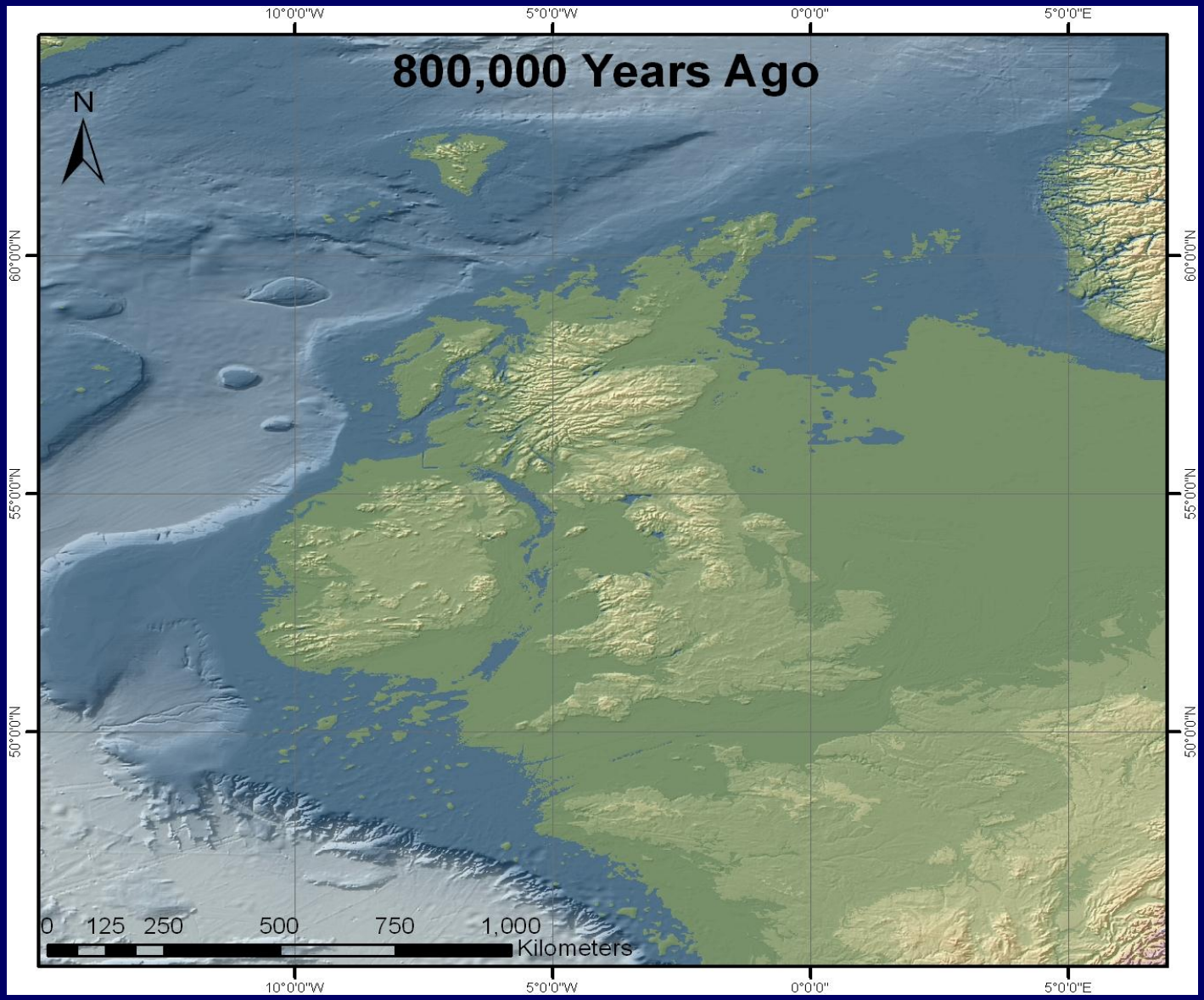
Kilometers


800,000 Years Ago
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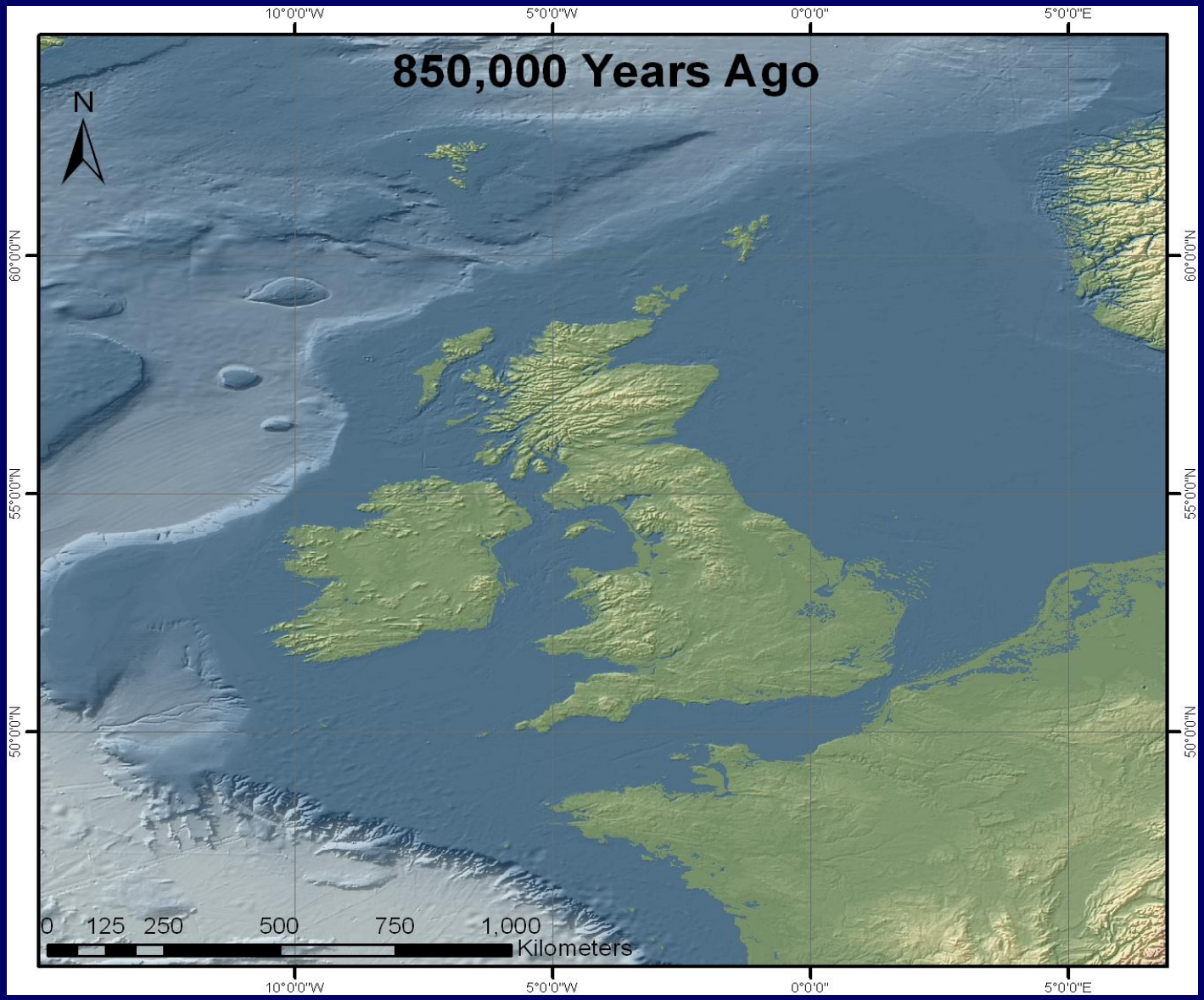
850,000 Years Ago
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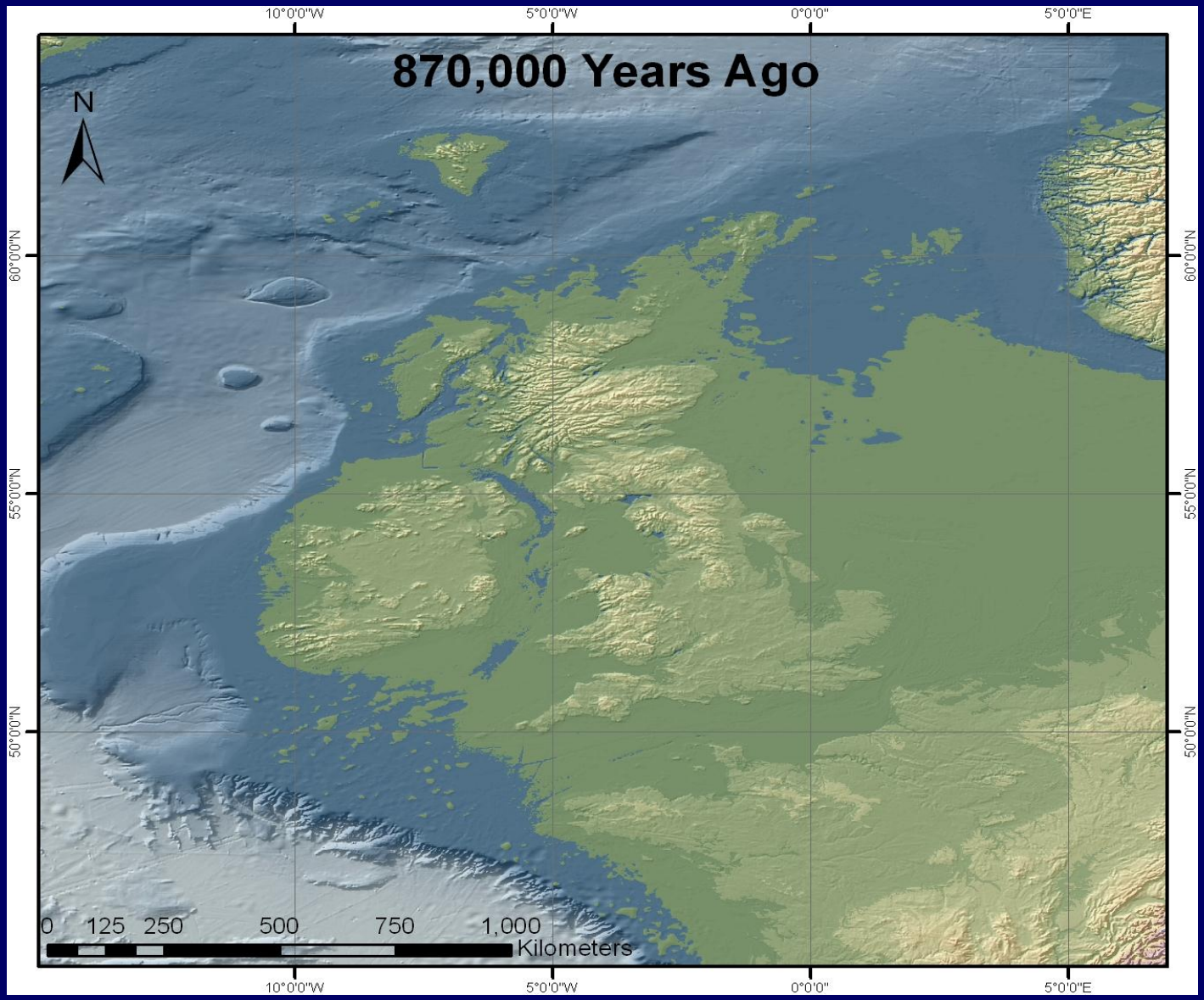
870,000 Years Ago
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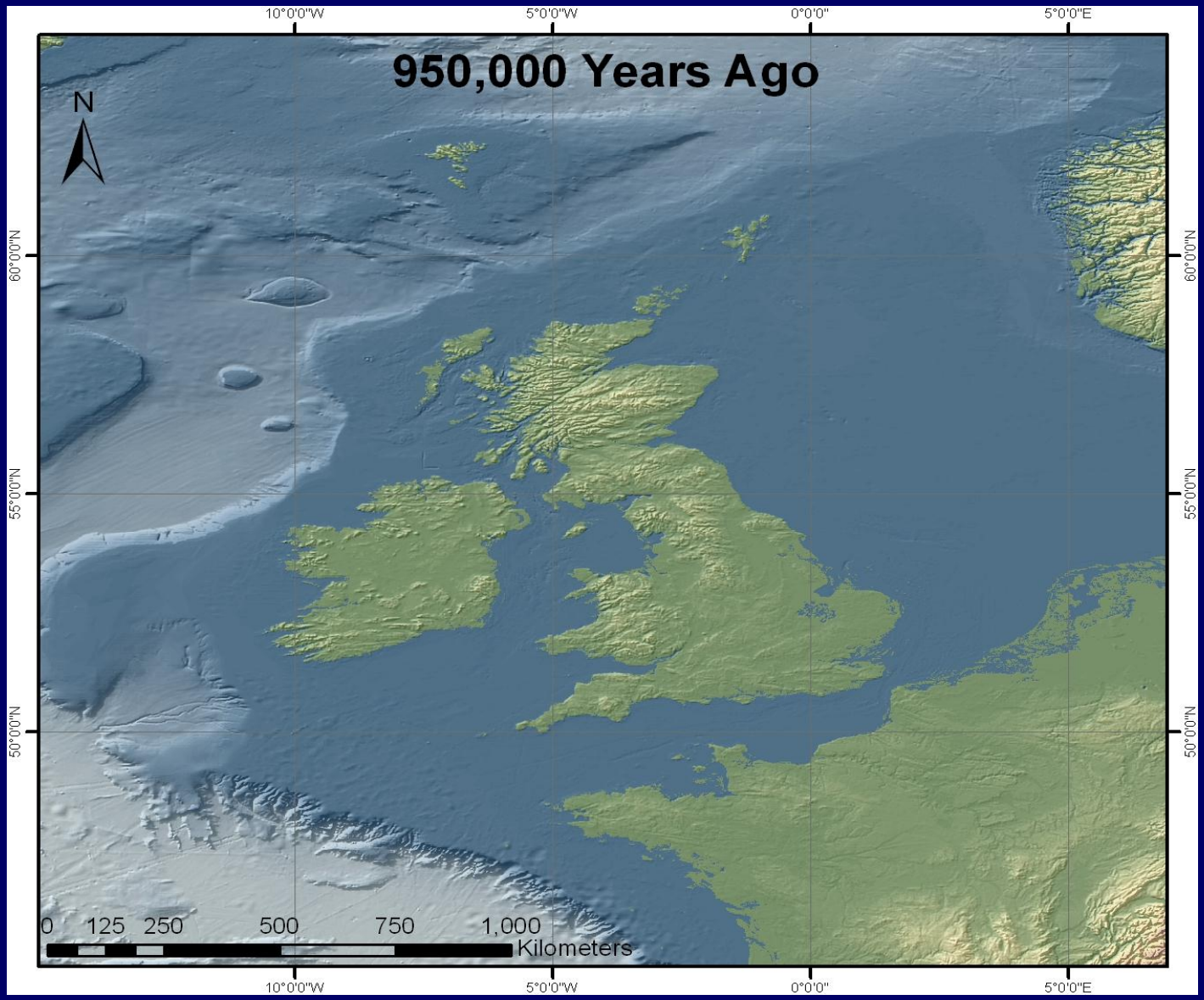
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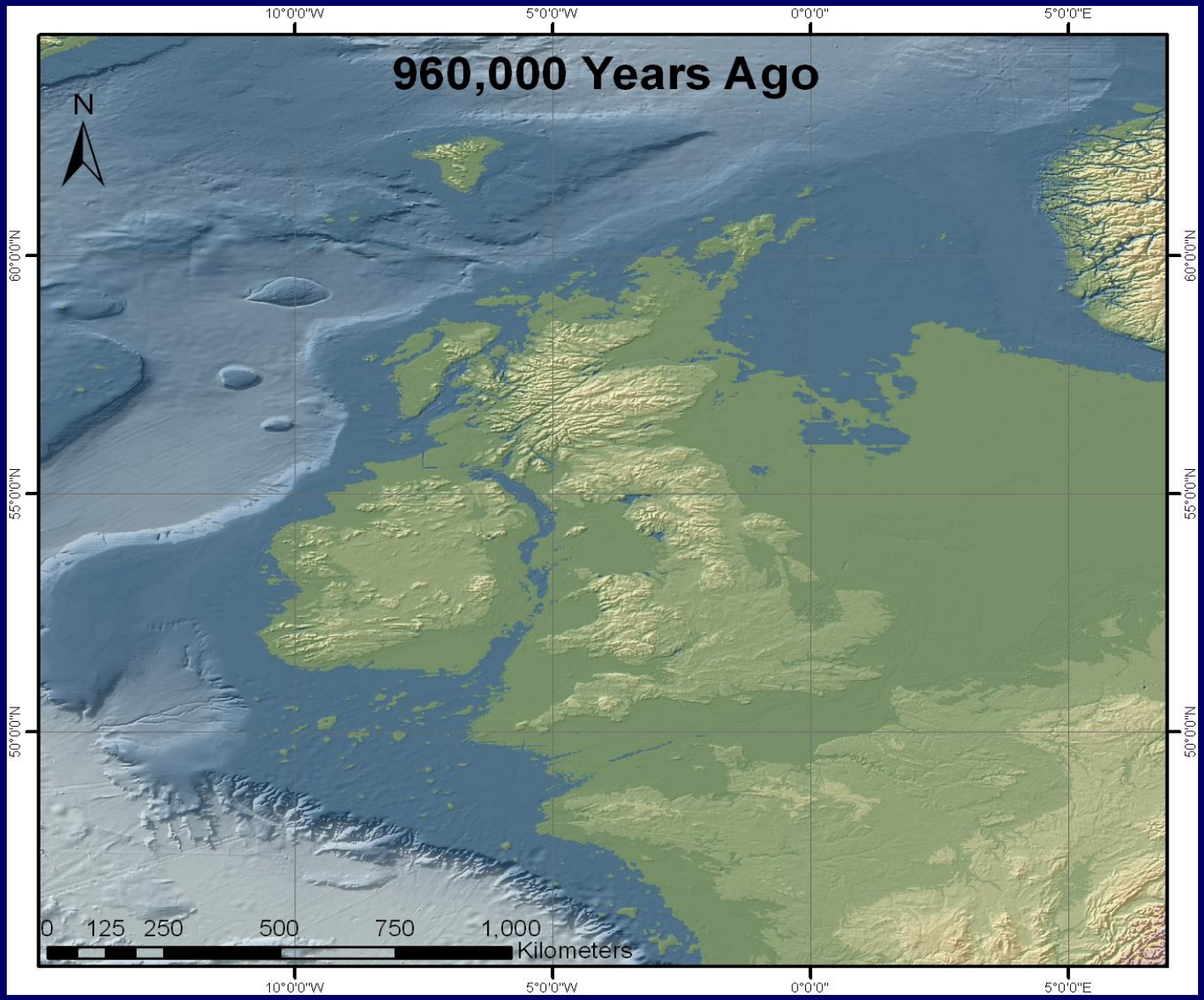
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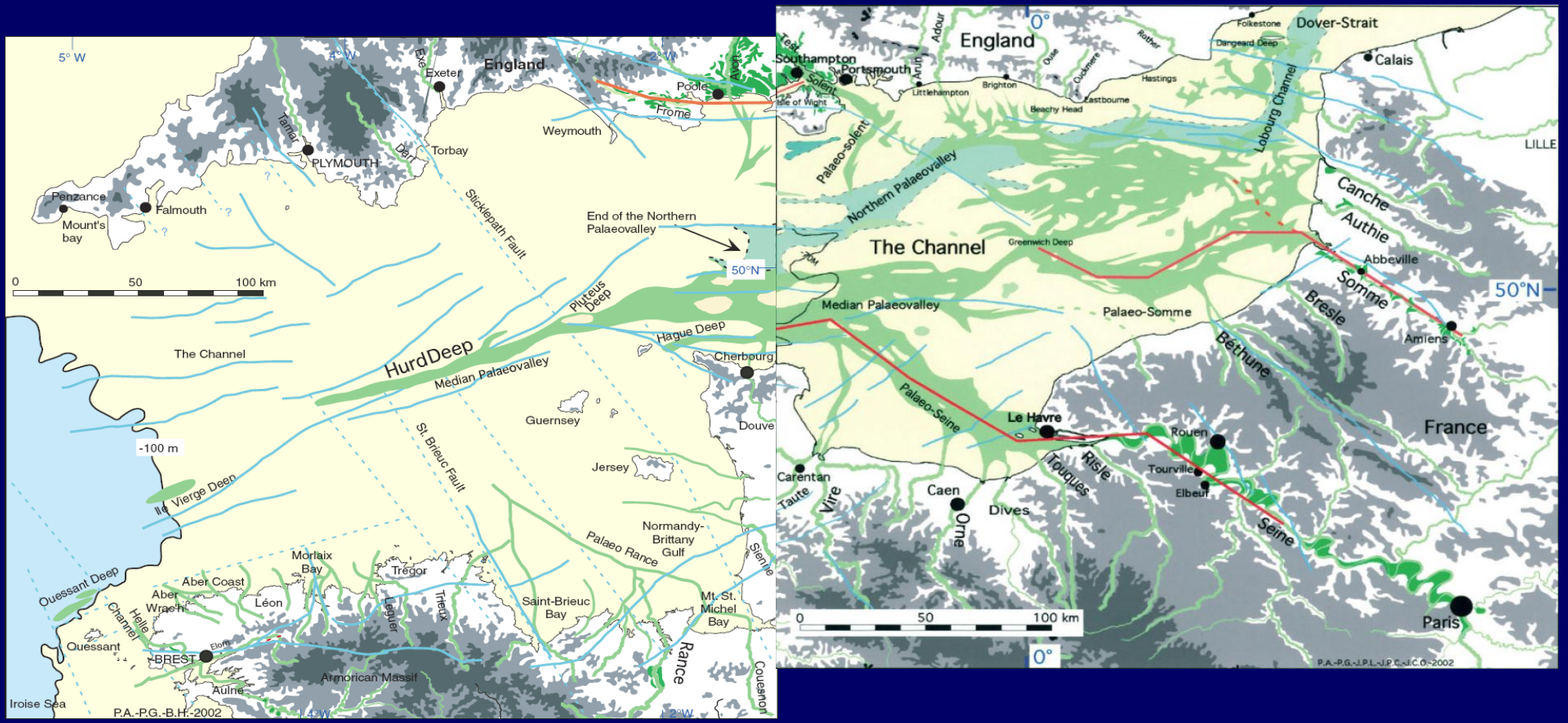
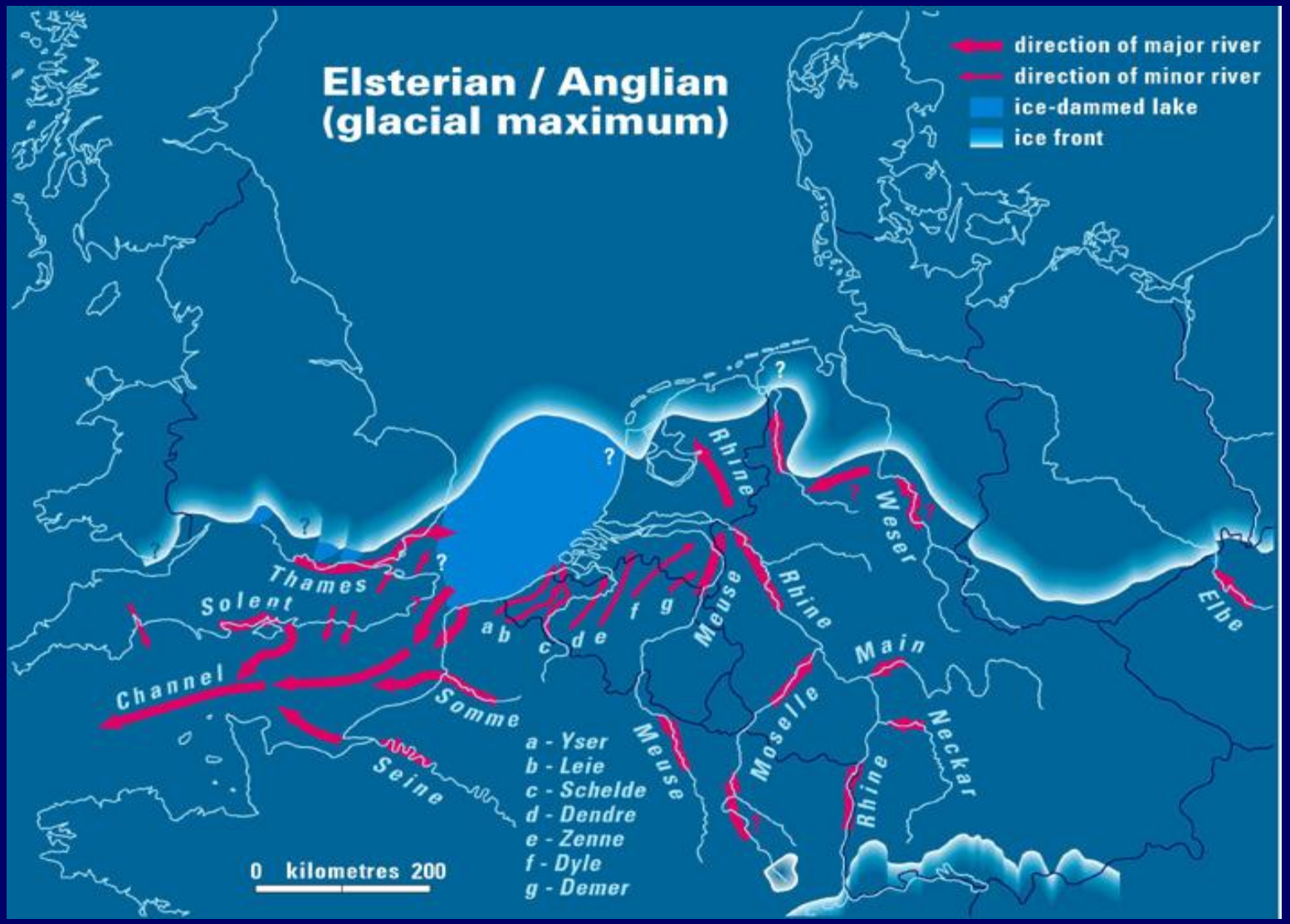


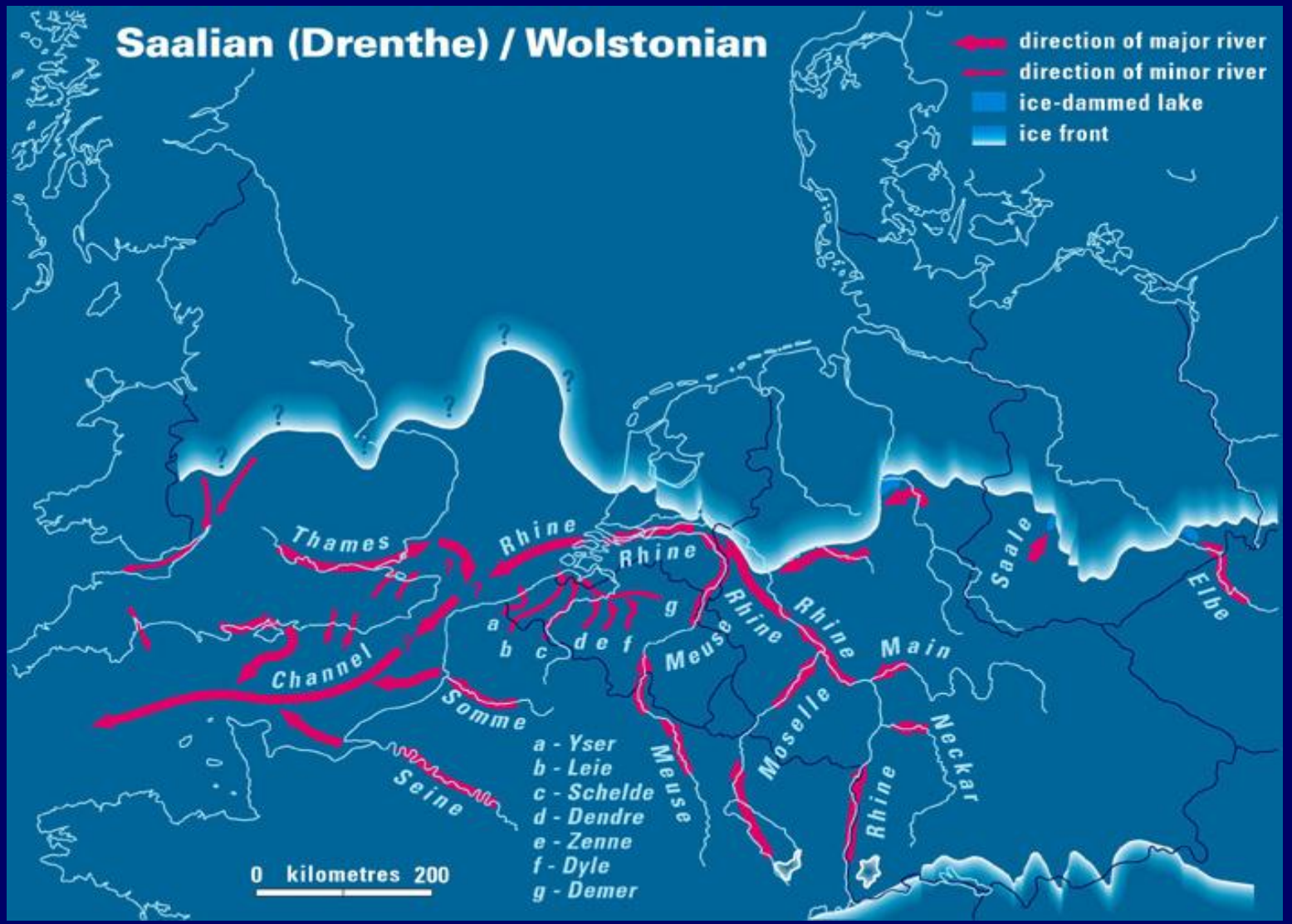
Antoine et al 2003

Elsterian/Anglian Glaciation MIS12 c. 420ka : Gibbard, 2007



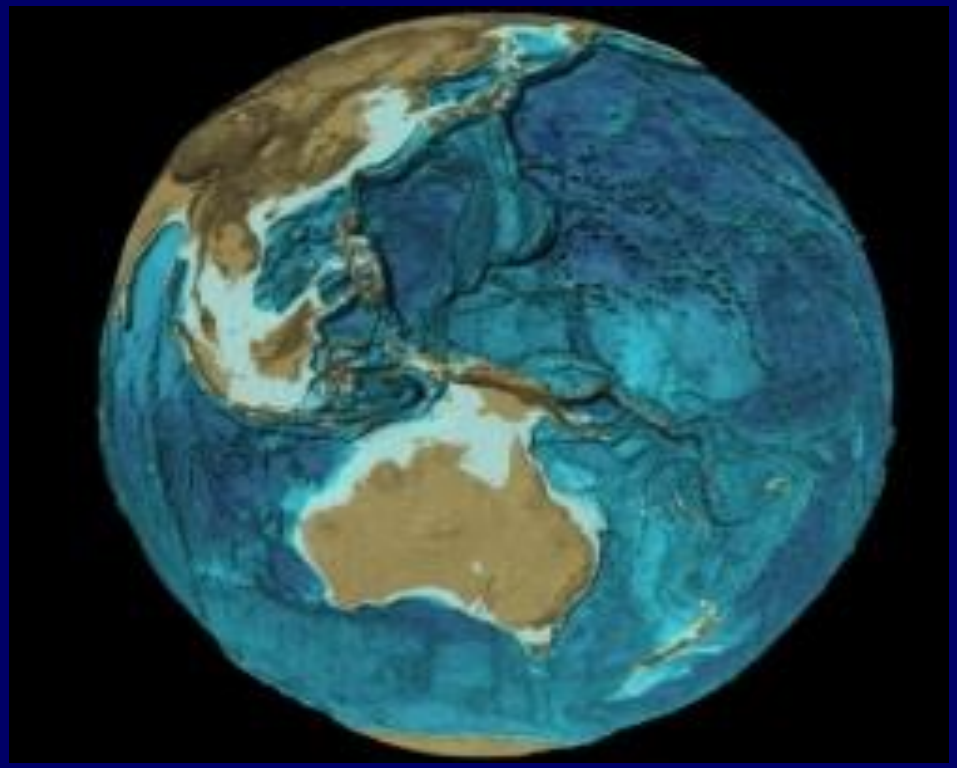
http://www.qpg.geog.cam.ac.uk/research/projects/nweurorivers/

Saalian/Wolstonian Glaciation MIS6 c. 130ka : Gibbard, 2007



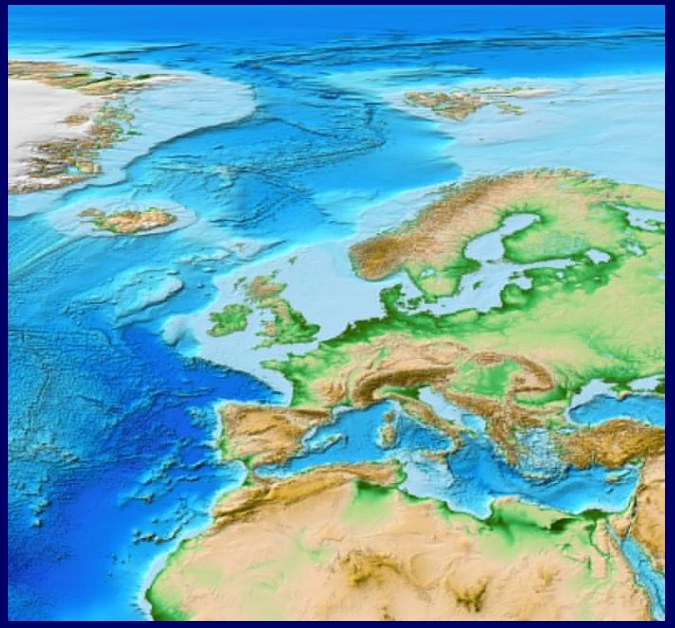
http://www.qpg.geog.cam.ac.uk/research/projects/nweurorivers/

Global Bathymetric Datasets: GEBCO



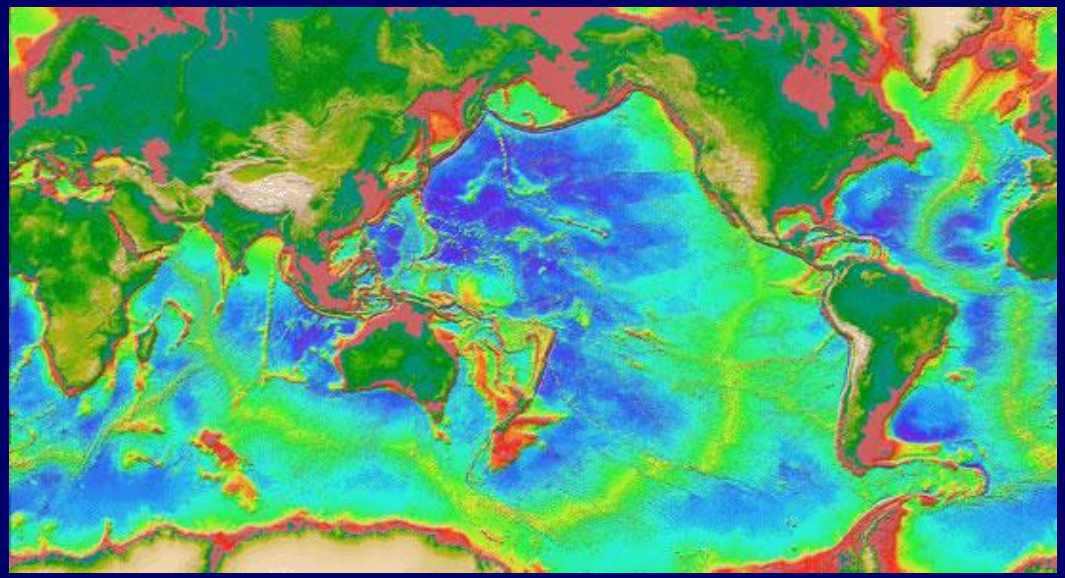
- GEBCO originally developed as a series of global digitized charts with the first digital version being released in 1994 with a standard contour interval of 500m.
- There is now a GEBCO one arc-minute grid updated in 2008 and a GEBCO_08 Grid at 30 arc-second grid format released in September 2010.
- Does also include land data from SRTM30 dataset.
- Work to a proxy mean sea level vertical datum this is a difficult issue
- These datasets can be downloaded from the **British Oceanographic Data Centre** website.

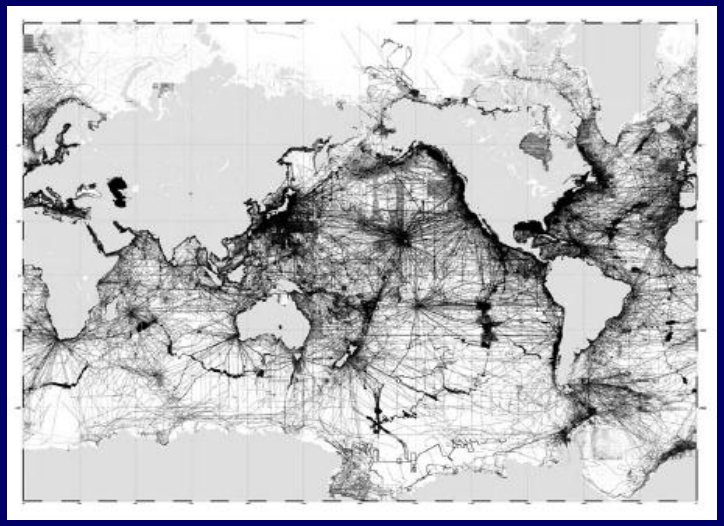
Global Topographic and Bathymetric Datasets: ETOPO5 – ETOPO1



- Integration of topographic and bathymetric datasets by NOAA to produce a truly global dataset with coverage from +90º to -90º latitude and -180º to +180º longitude. At 1 arc minute resolution.
- Ice surface and bedrock models available.
- Bulk of ocean bathymetric data based on GEBCO estimated Seafloor Bathymetry.
- Thus data derived from bathymetric soundings stitched with SRTM30 Topography and GLOBE Topography.
- Available from **NOAA Geophysical Data Centre Bathymetric viewer.**

Global Topographic and Bathymetric Datasets: Smith & Sandwell

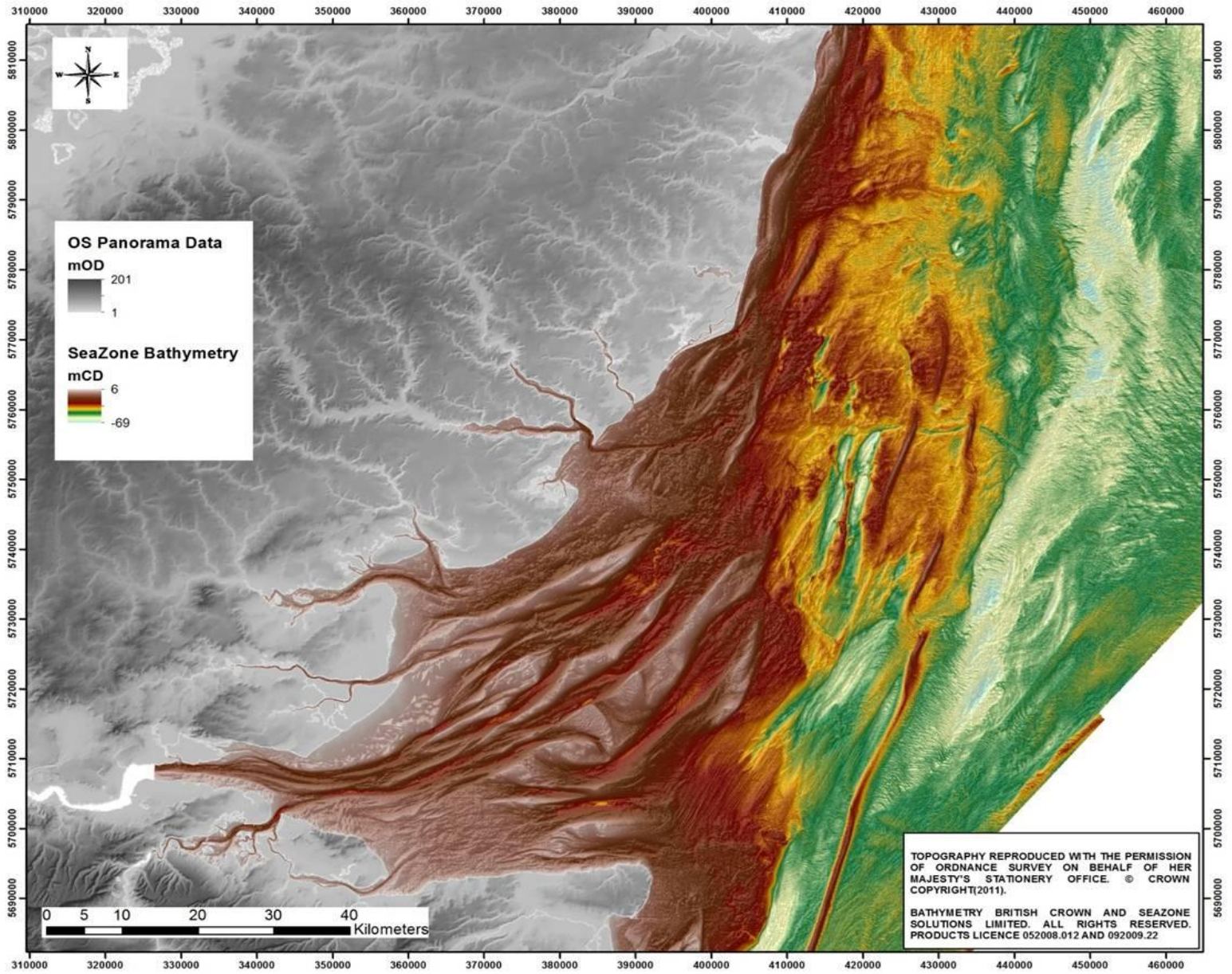




- An alternative approach developed by Smith & Sandwell (1997). Known as SRTM30_PLUS
- Combined available depth soundings with high resolution marine gravity information from Geosat and ERS-1 spacecraft. Subsequent updates use latest altimeter-derived gravity models.
- Versions updated continually with latest version integrating SRTM30 data and is at a 30 arc second spatial resolution.
- Available from SCRIPPS website

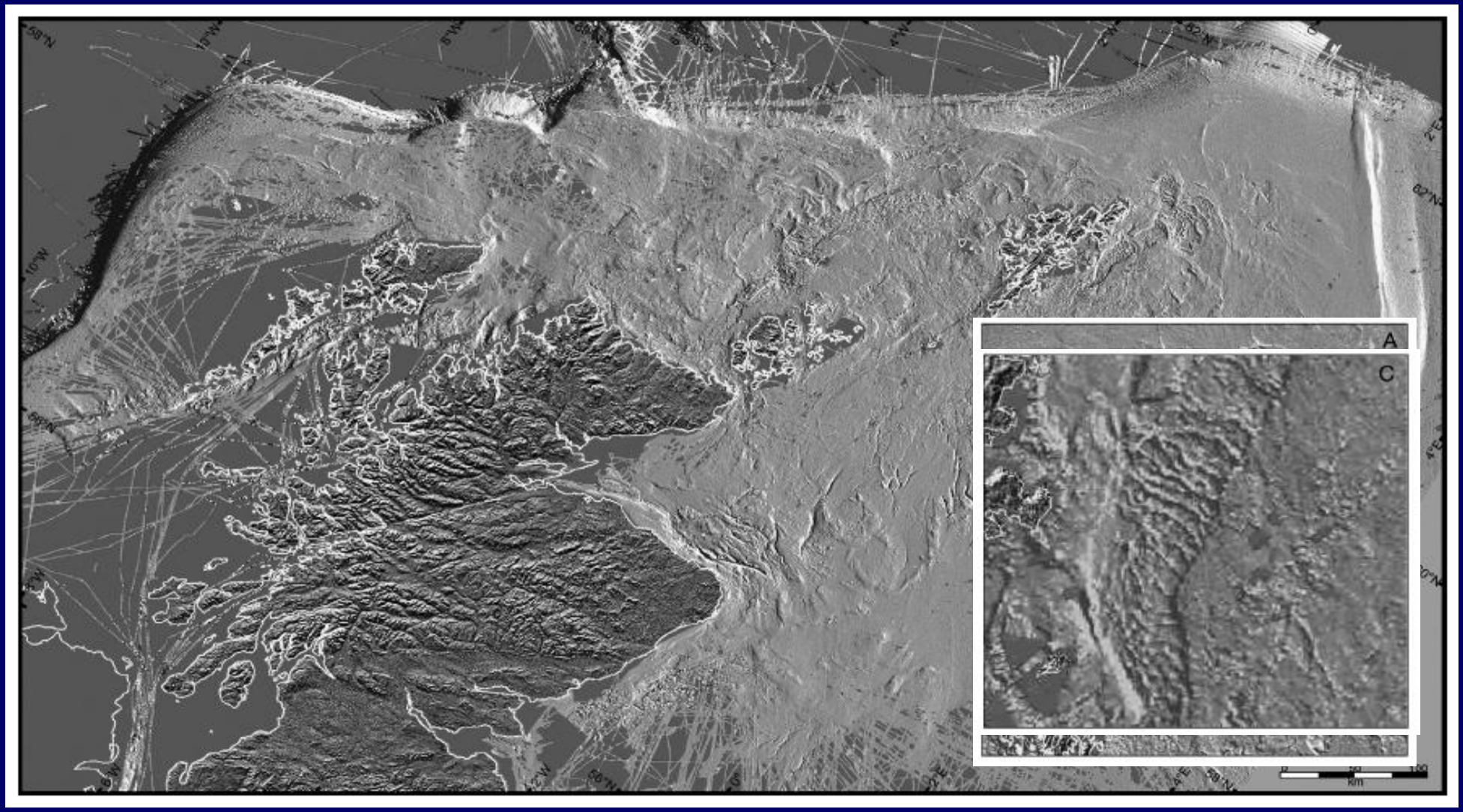
  http://topex.ucsd.edu/marine_topo/

The source for much of this data is available from the NOAA National Geophysical Data Center Bathymetric Data Reviewer.



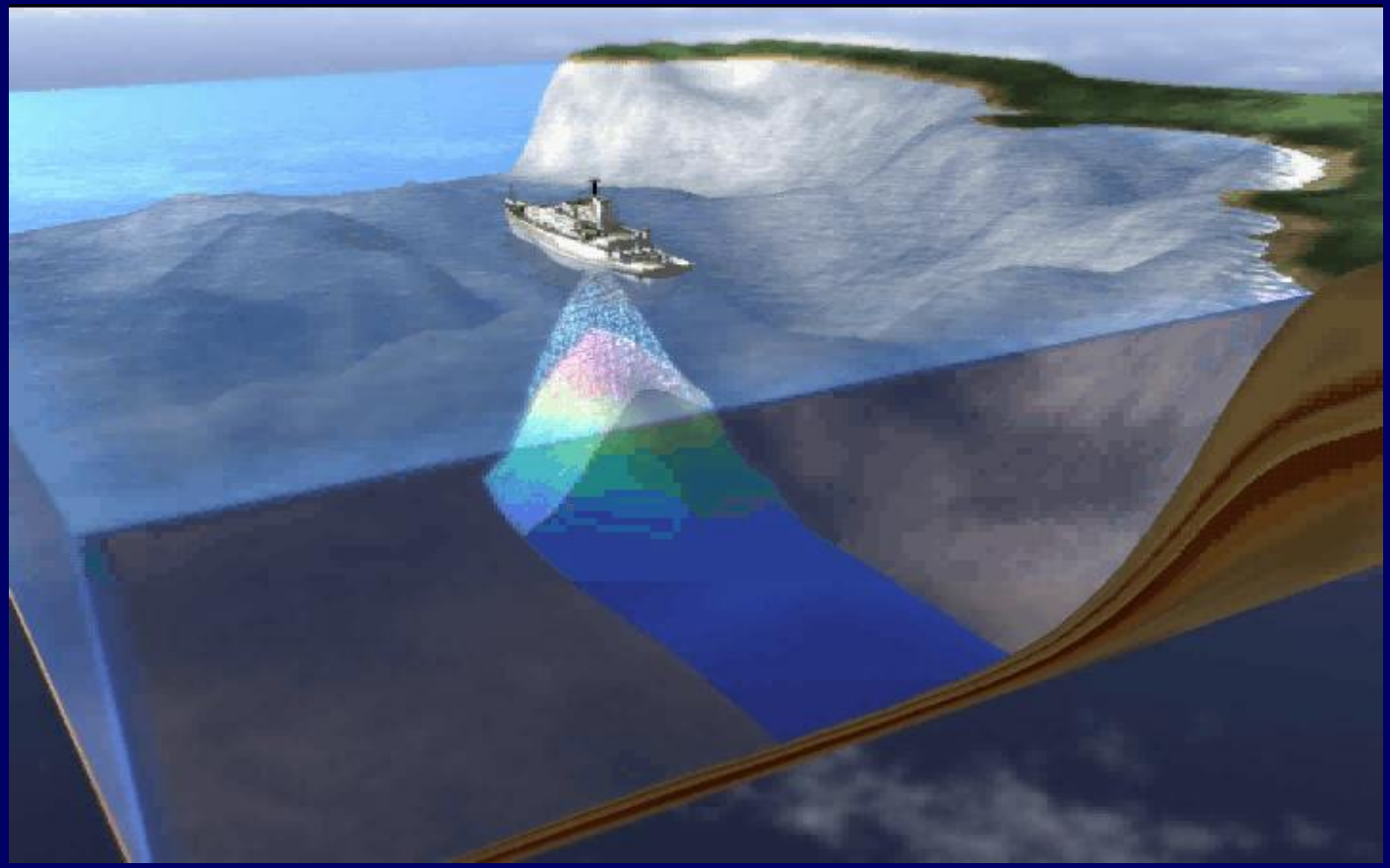
Deconflicted UKHO Bathymetry Gridded at 30 x 20 m bin

Courtesy Seazone Ltd/UKHO

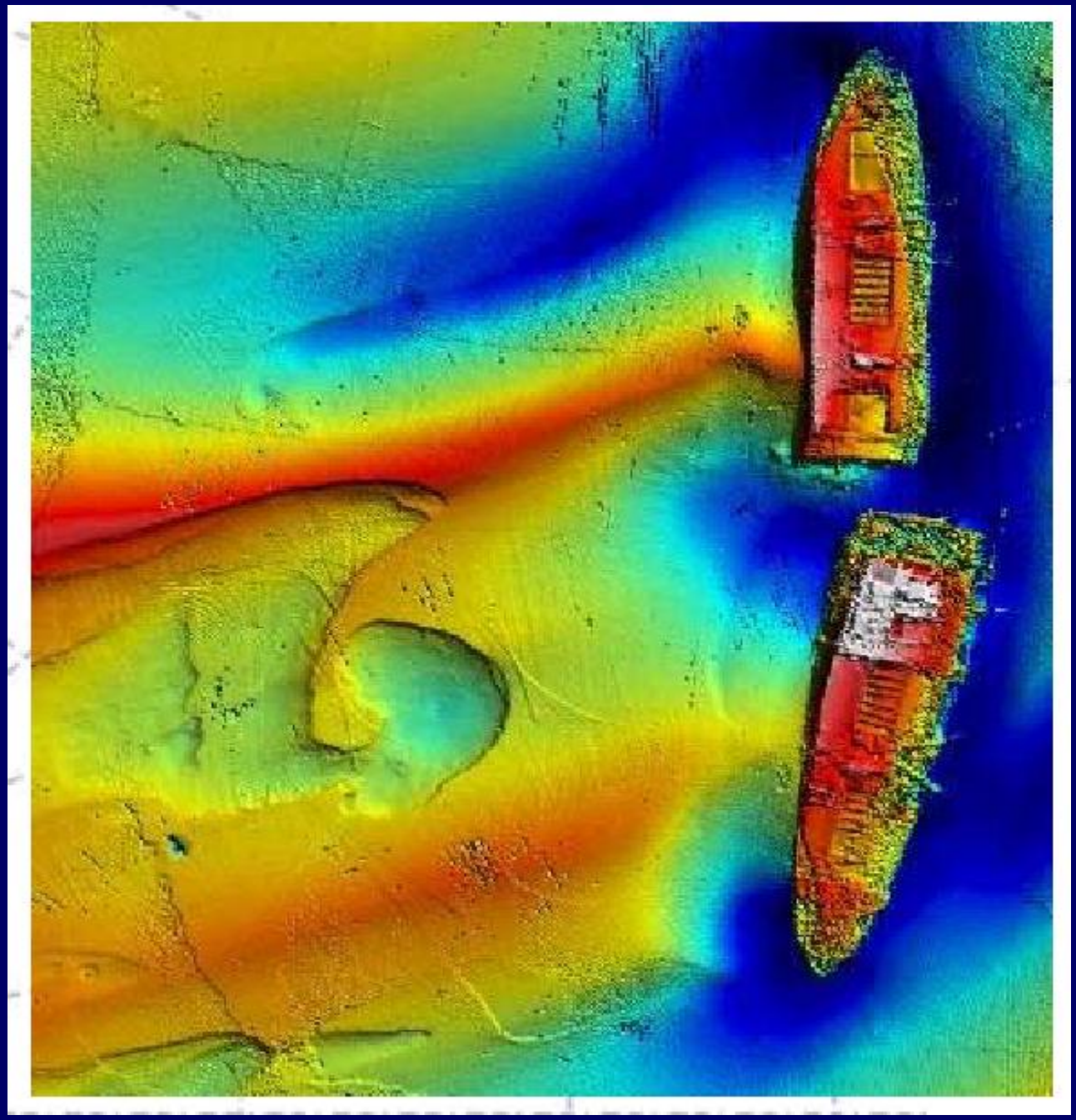


Bradwell et al., 2008. Olex bathymetry of the northern North Sea – derived from the North Sea Fishing Fleet
http://www.olex.no/index_e.html

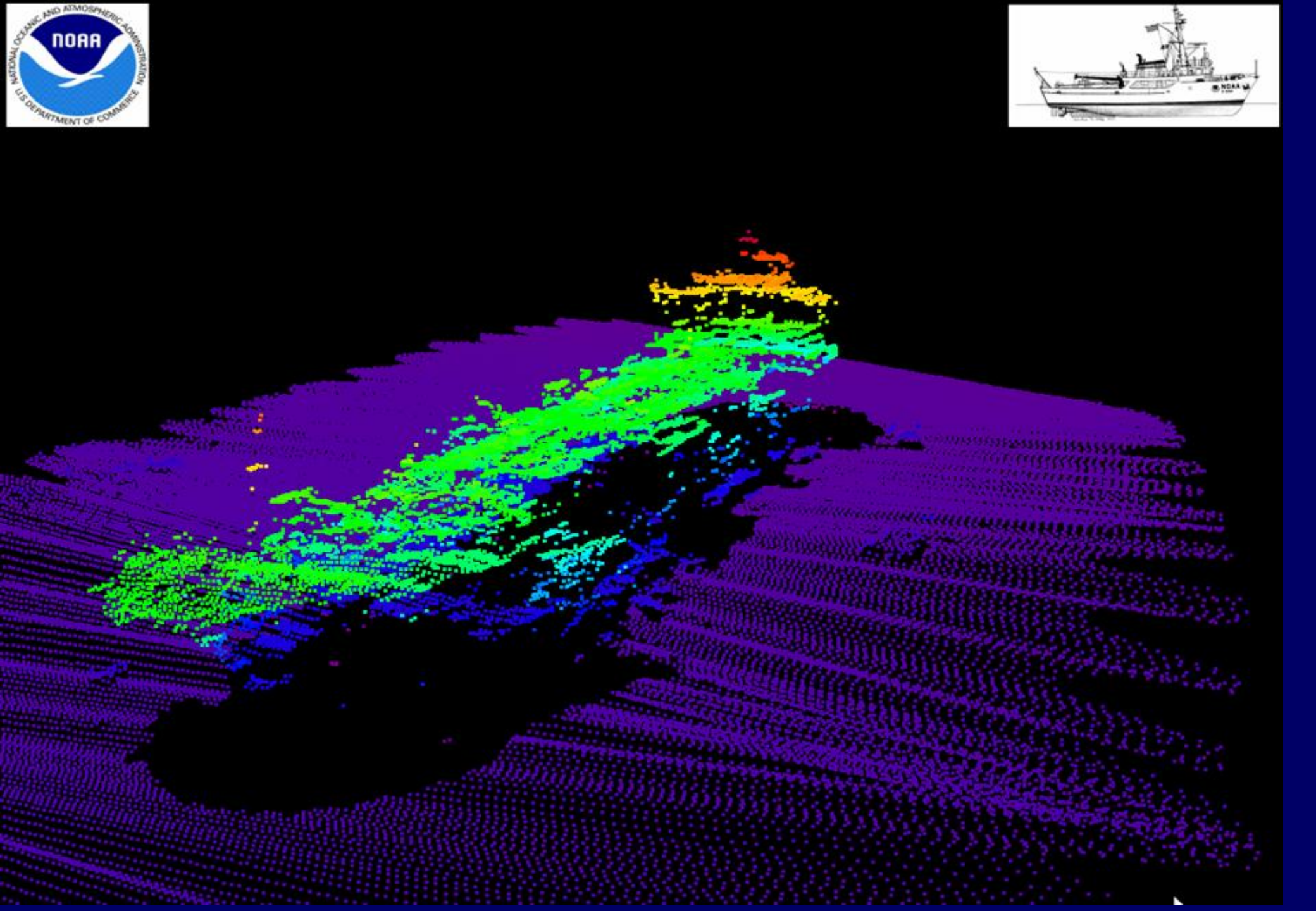
Swath Bathymetry Systems

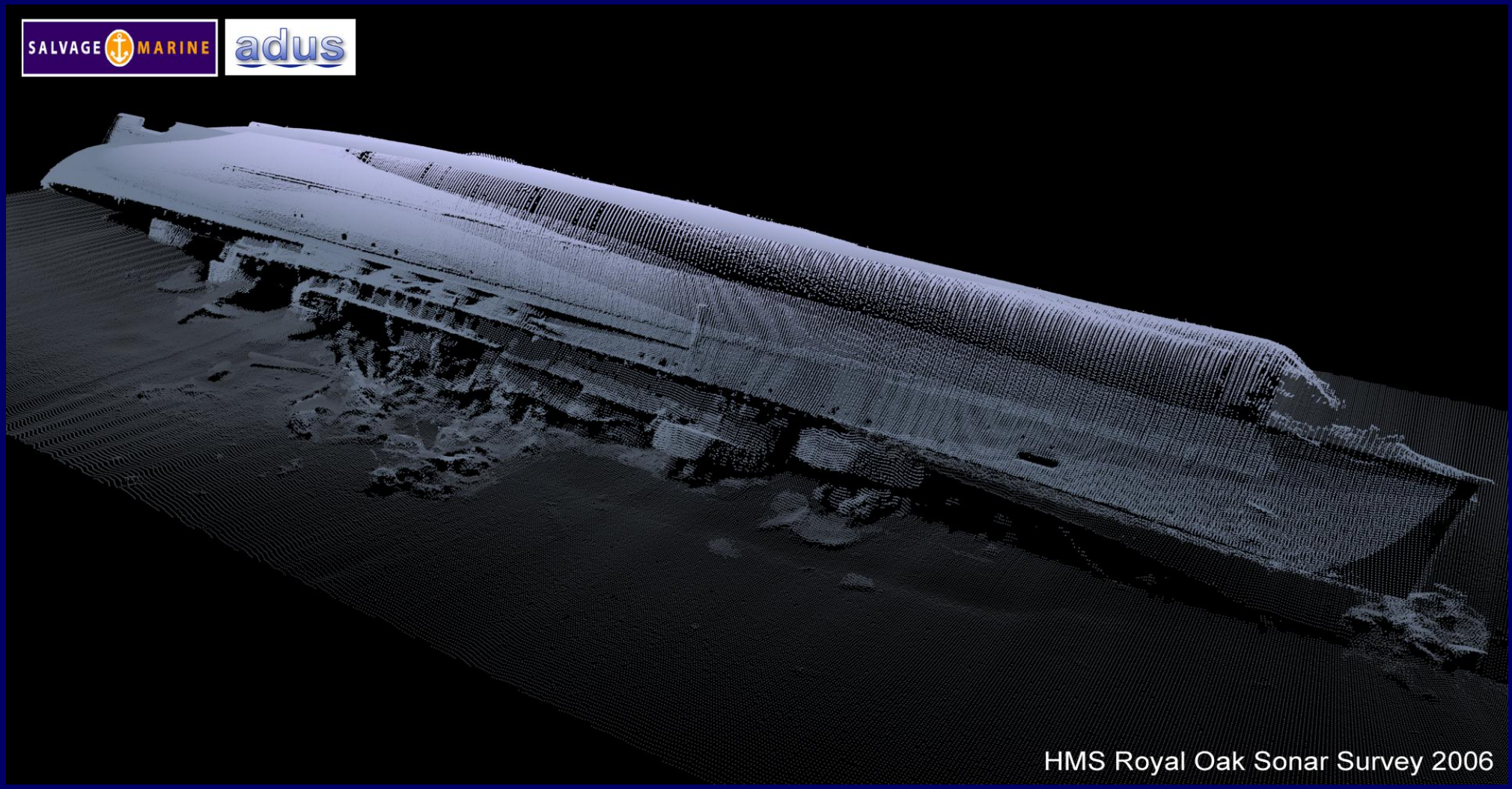


- Beam formers (multibeams) - MBES
- Phase Measuring Bathymetric Sonar – aka: Interferometric Systems; Bathymetric Side-Scan; Vernier Interferometer; Wide Swath (or swathe) Sonar



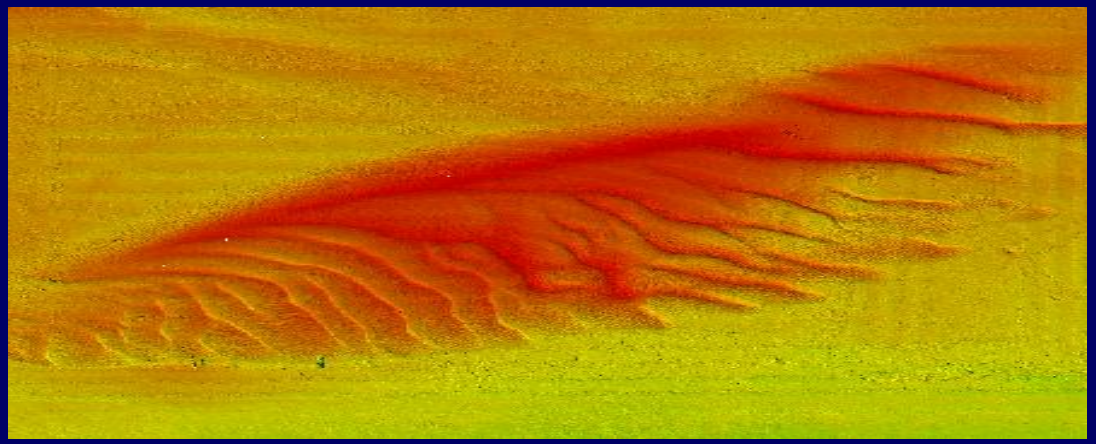
RESON

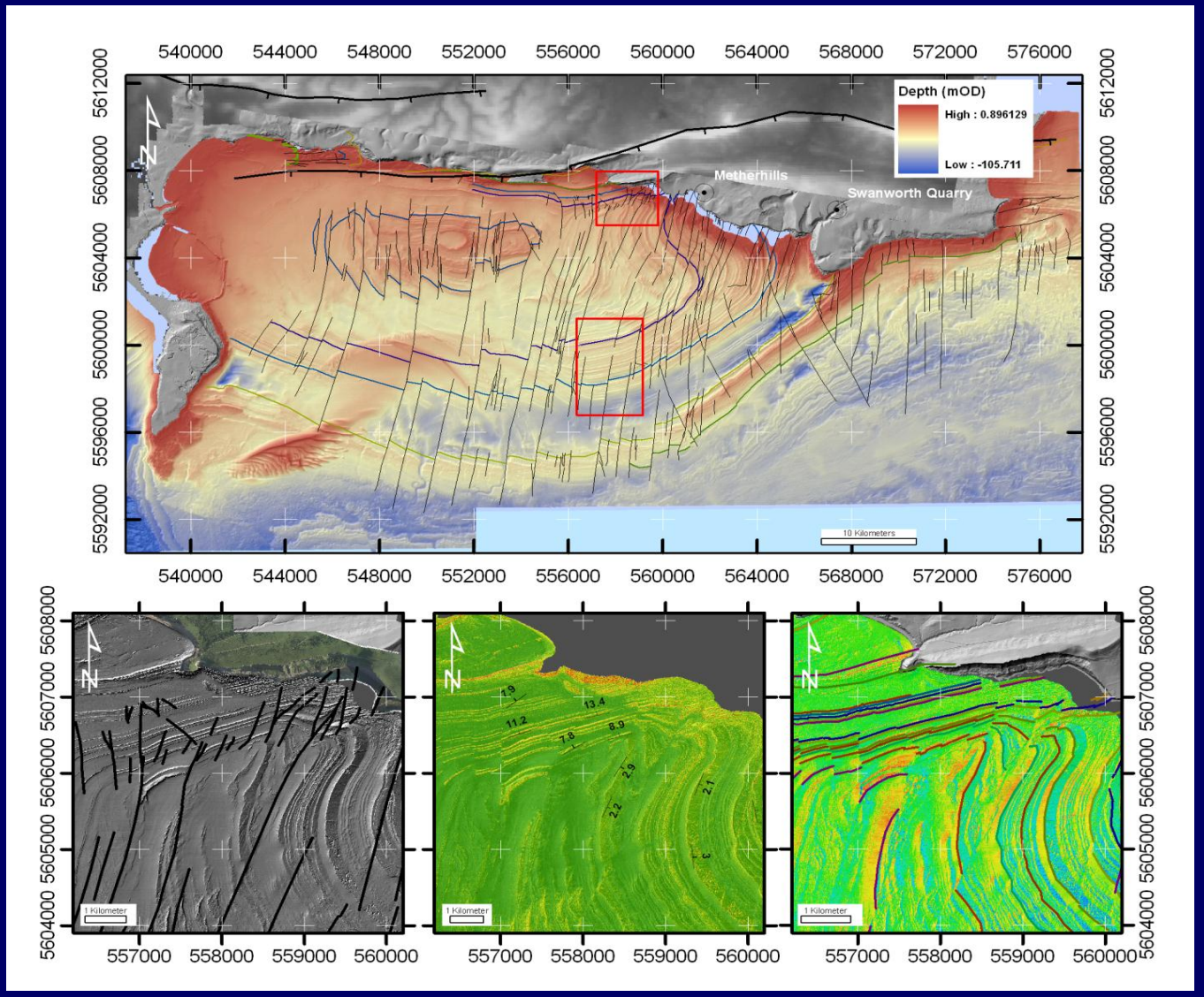

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE


SALVAGE MARINE
adus
HMS Royal Oak Sonar Survey 2006

DORIS Dataset

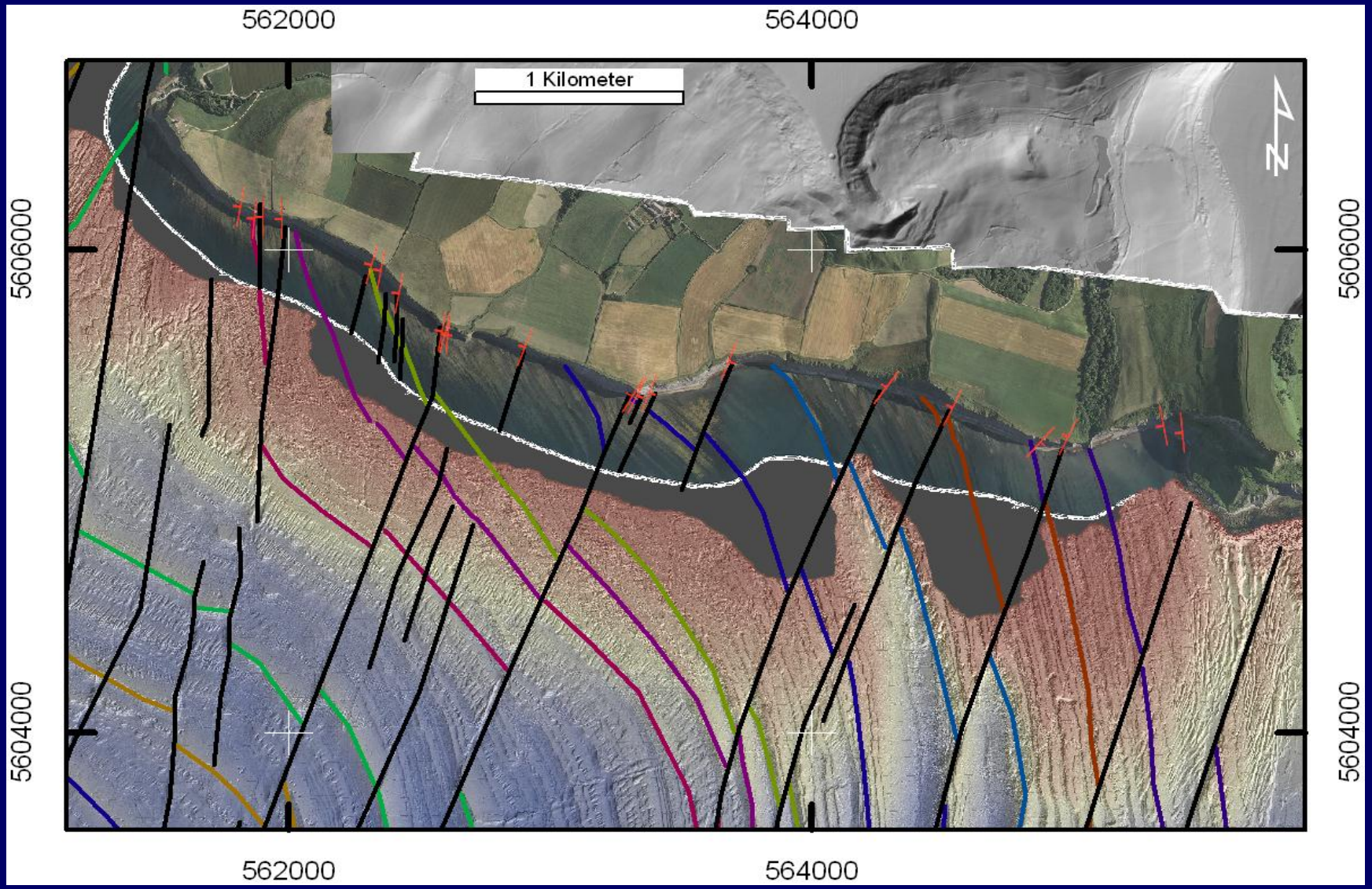
- 100% cover multibeam survey of 800km^2 (bathymetry & backscatter)
- ~150 x 500m seabed video/still photo transects (SeaStar Survey Ltd)
- Coastal strip LIDAR and aerial photography (CCO)
- Intertidal habitat ground-truthing survey
- Seasearch volunteer seabed habitat/species survey

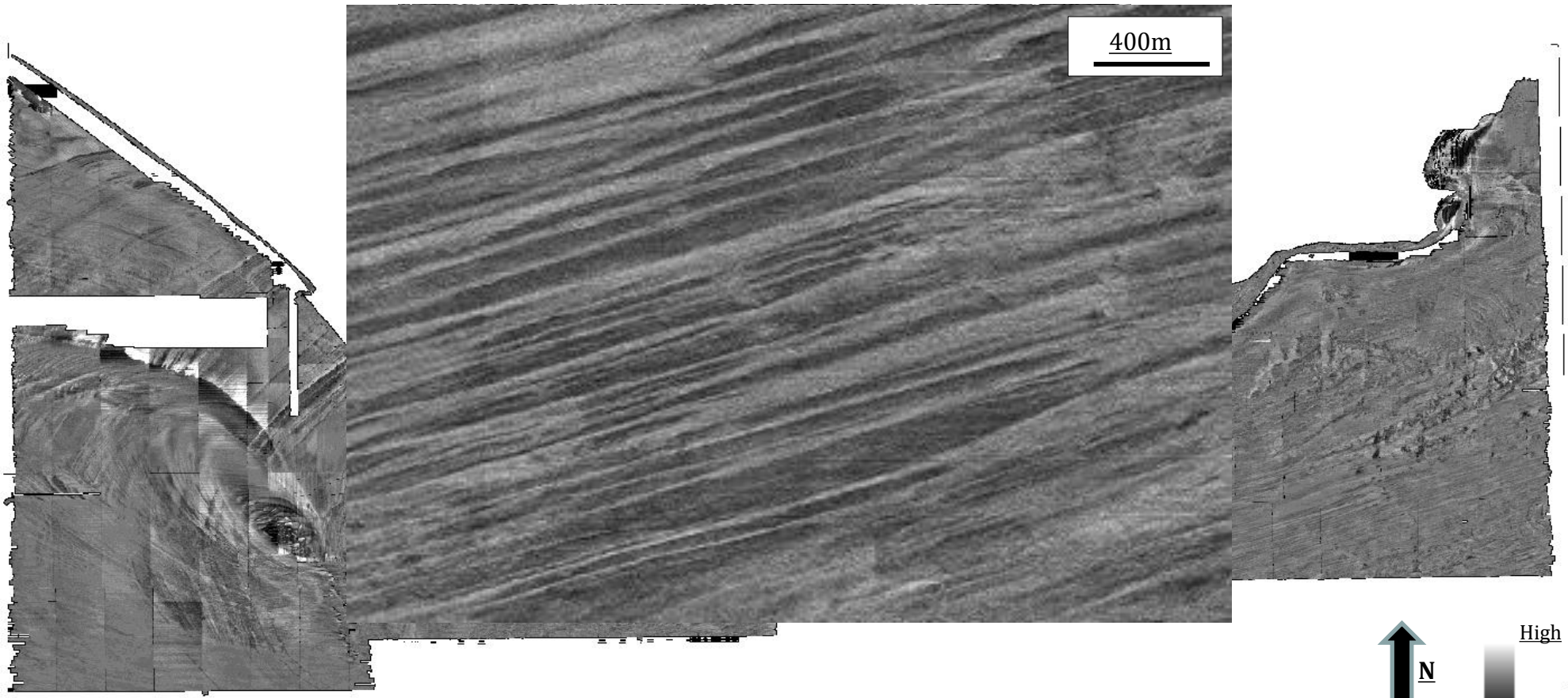




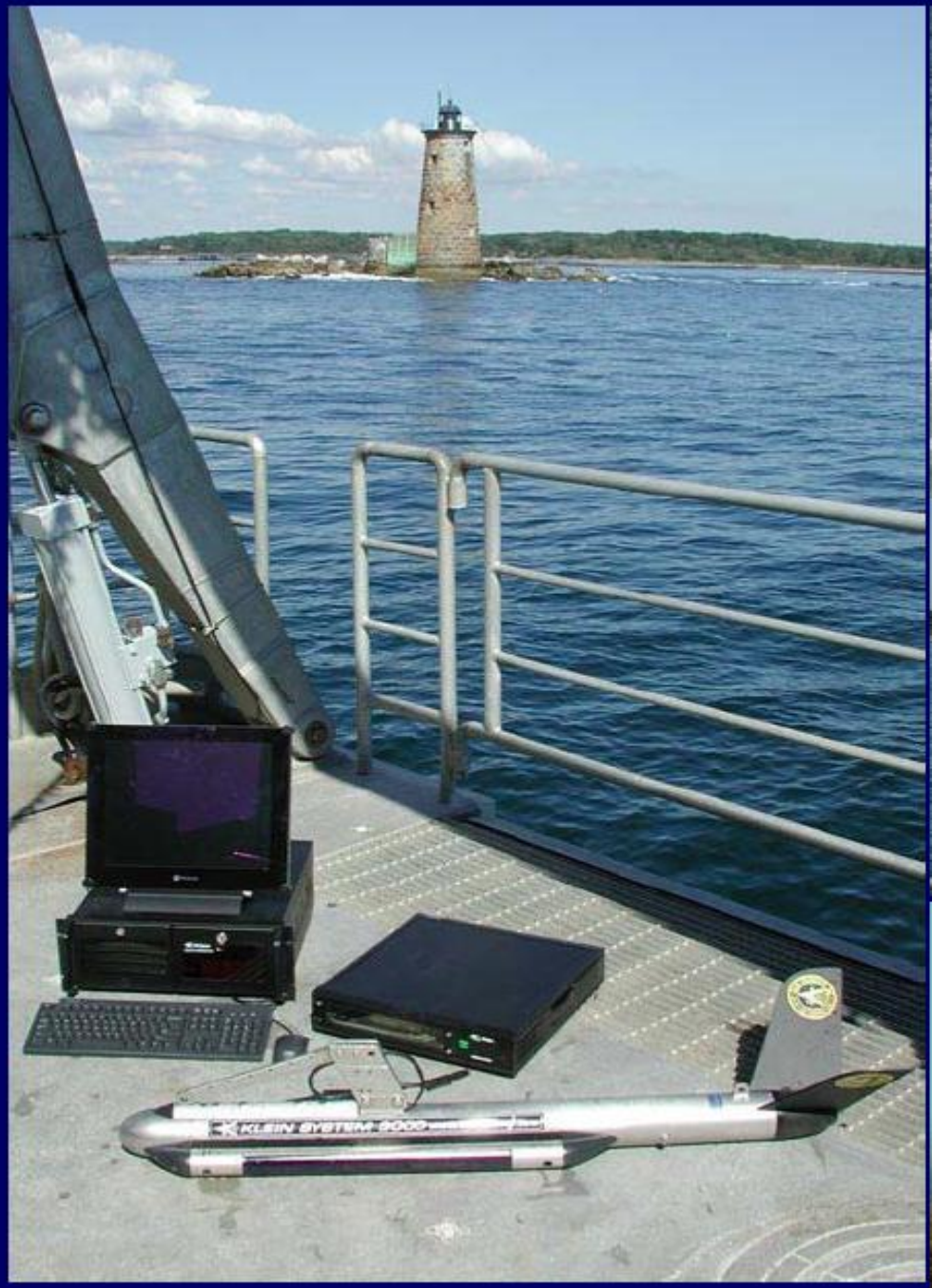
Geology of Offshore Dorset
Sanderson et al.,
submitted

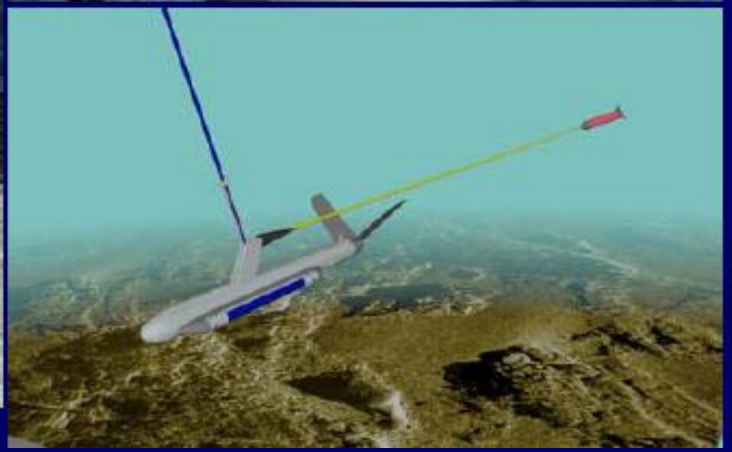
Geology of Offshore Dorset: Sanderson et al., submitted

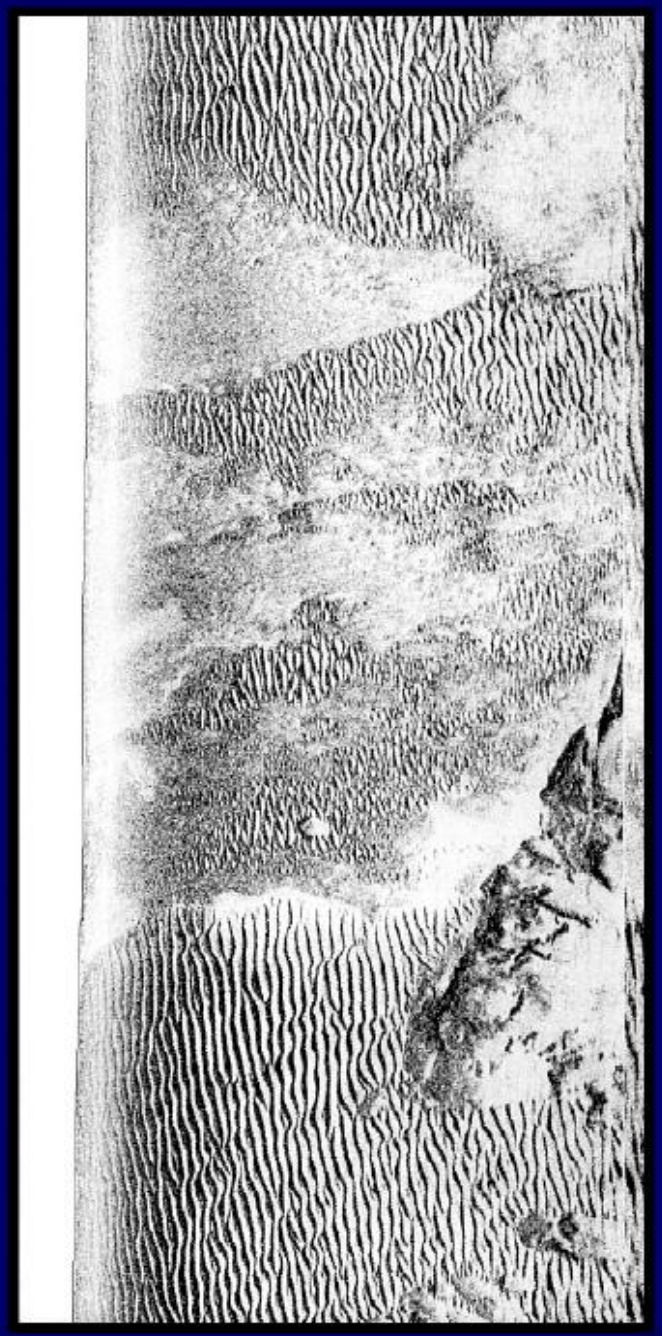


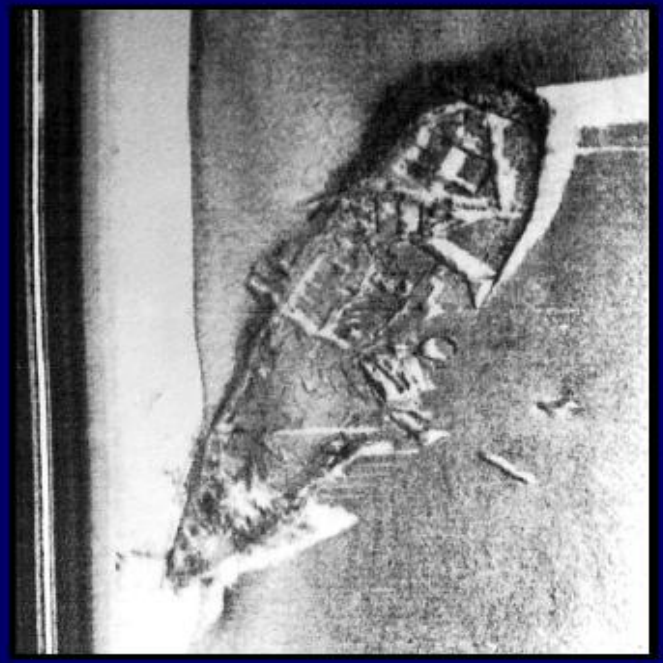


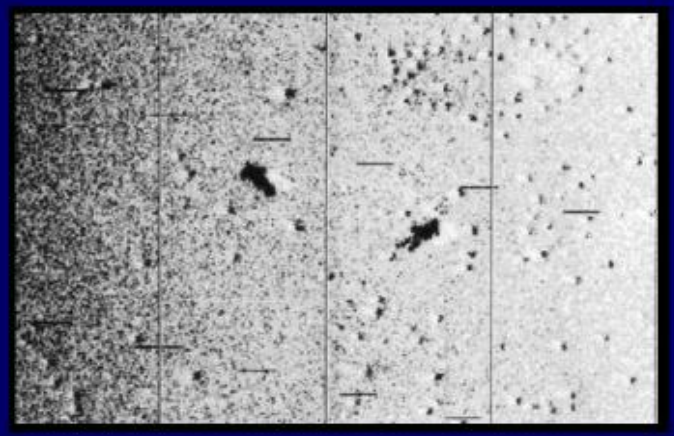
Backscatter of Dorset seabed between Chesil Beach and Swanage Bay. Bin size 0.25m.


KLEIN SYSTEM 5000

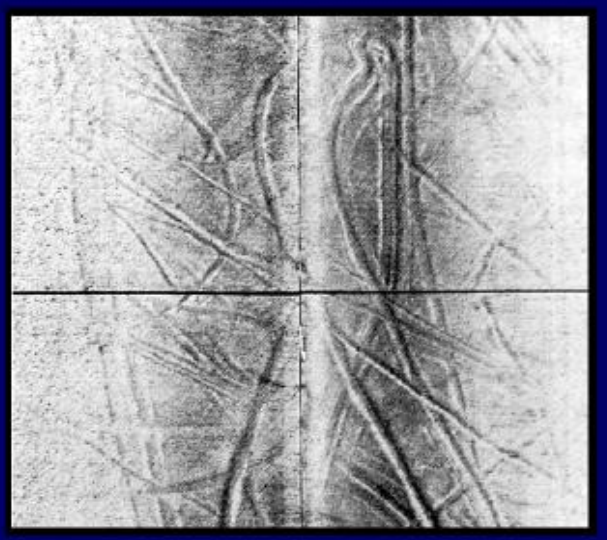


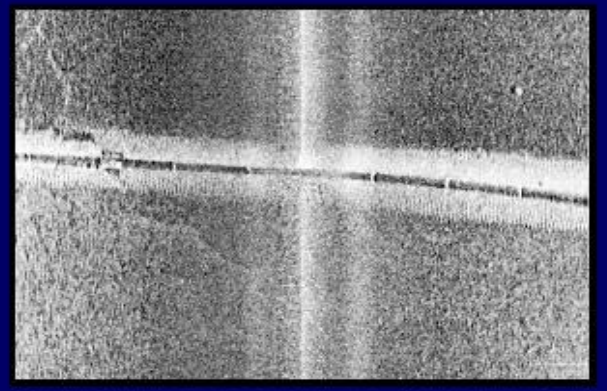


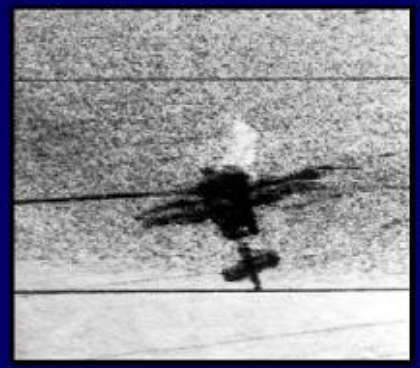




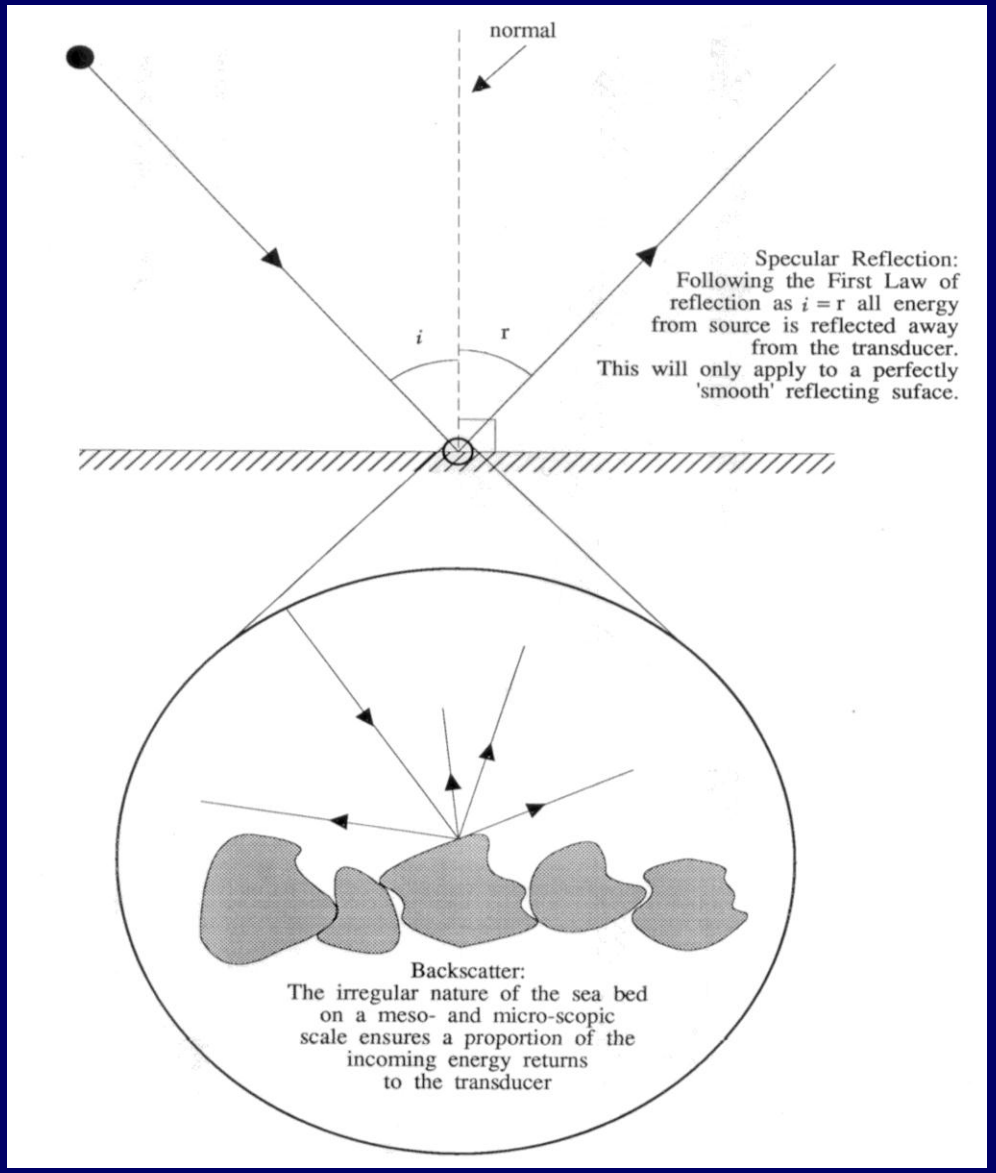
Klein Associates Inc., 2005

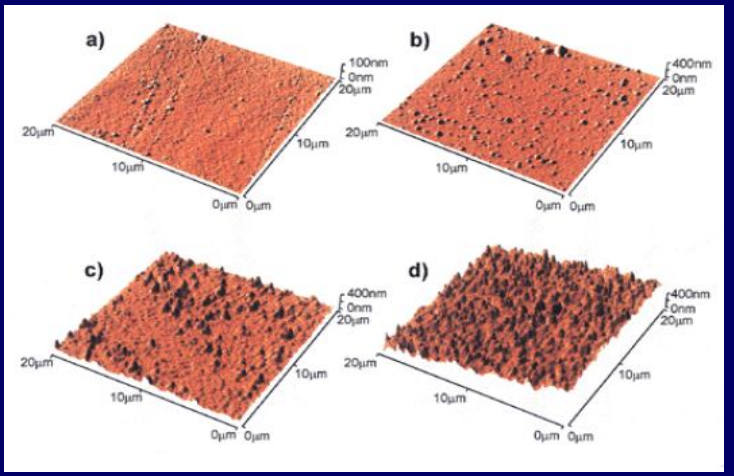


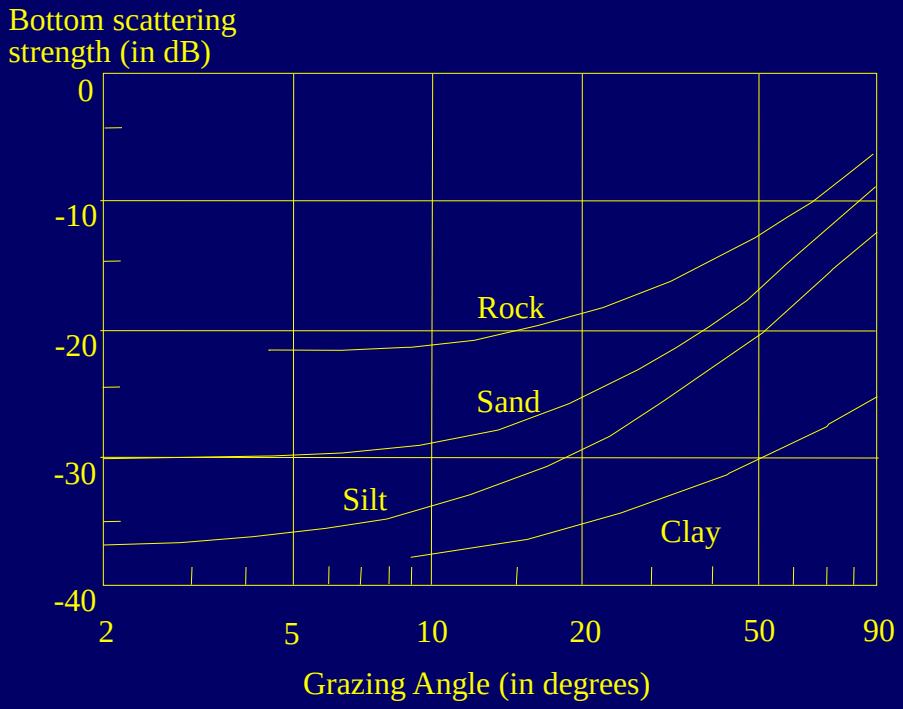


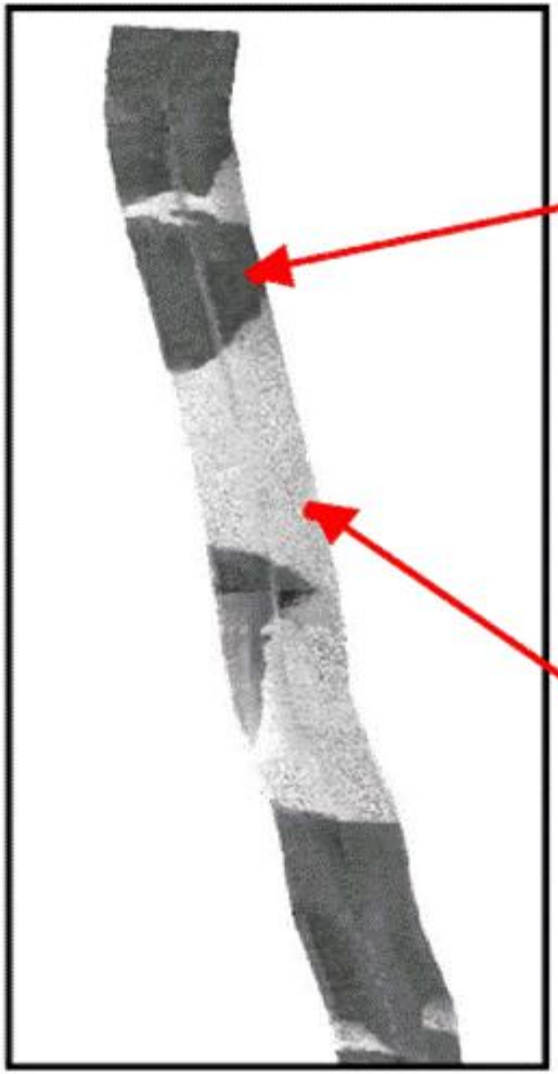


First Law of Reflection and Backscatter

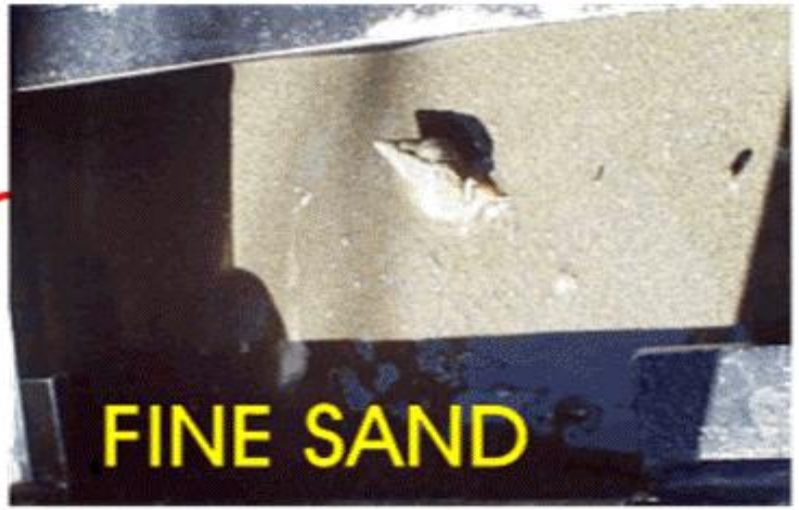








300 0 300 600 Meters



J.E. Hughes Clarke, 2005, OMG/UNB

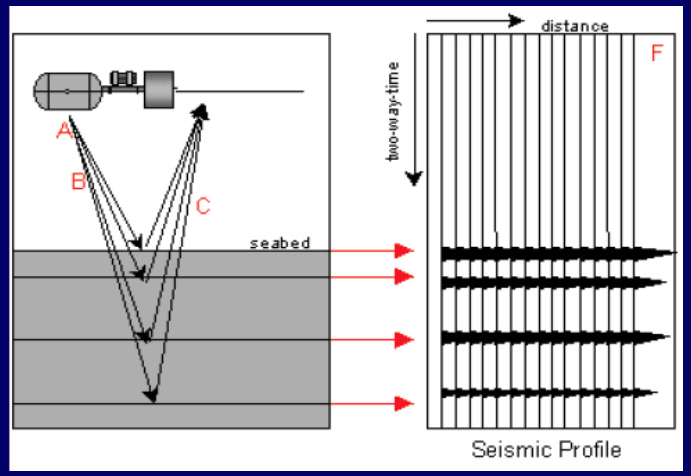
Mosaicing

Processed side-scan data comprises picture elements (pixels), organised into one or several images.

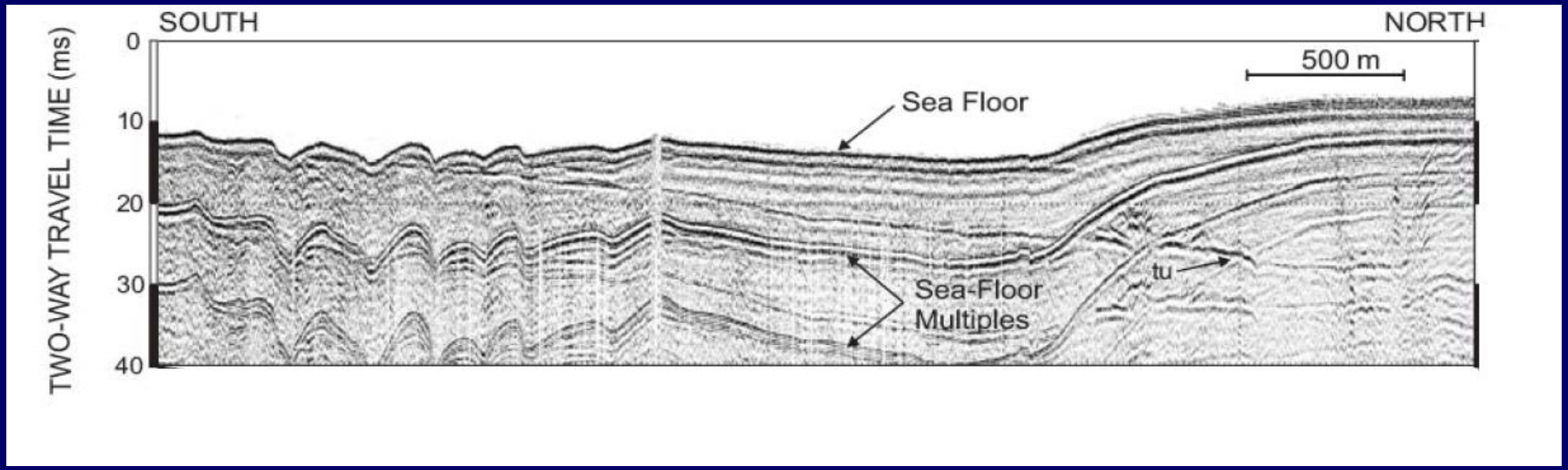
These pixels are located by geo-referencing, usually rectified to a particular map system (Mercator, UTM etc.).

Mosaics are effectively series of parallel side-scan passes pasted together to form an image covering large areas, but maintaining resolution.

Single Channel Sub-bottom Profiling



A. The method uses an energy source to trigger a pressure wave in the water;
B. The wave propagates away from the source and is reflected at sub-bottom horizons;
C. The reflected wave propagates back and is recorded by pressure-sensitive hydrophones;
F. Successive traces build up a seismic 'section' or 'profile' whose vertical axis is measured in two-way- time (TWT) and horizontal axis is distance.



Accelerating Water Masses: Electro-dynamic systems

Boomer: An implosive source. A capacitor bank is discharged through a flat spiral coil. Eddy currents are generated in a rigid, aluminum, plate beneath the coil. The resulting magnetic fields causes the rapid repulsion of the plate and the creation of a shock wave. The source is usually mounted on a towed catamaran and a separate 20 element hydrophone is used for a receiver.

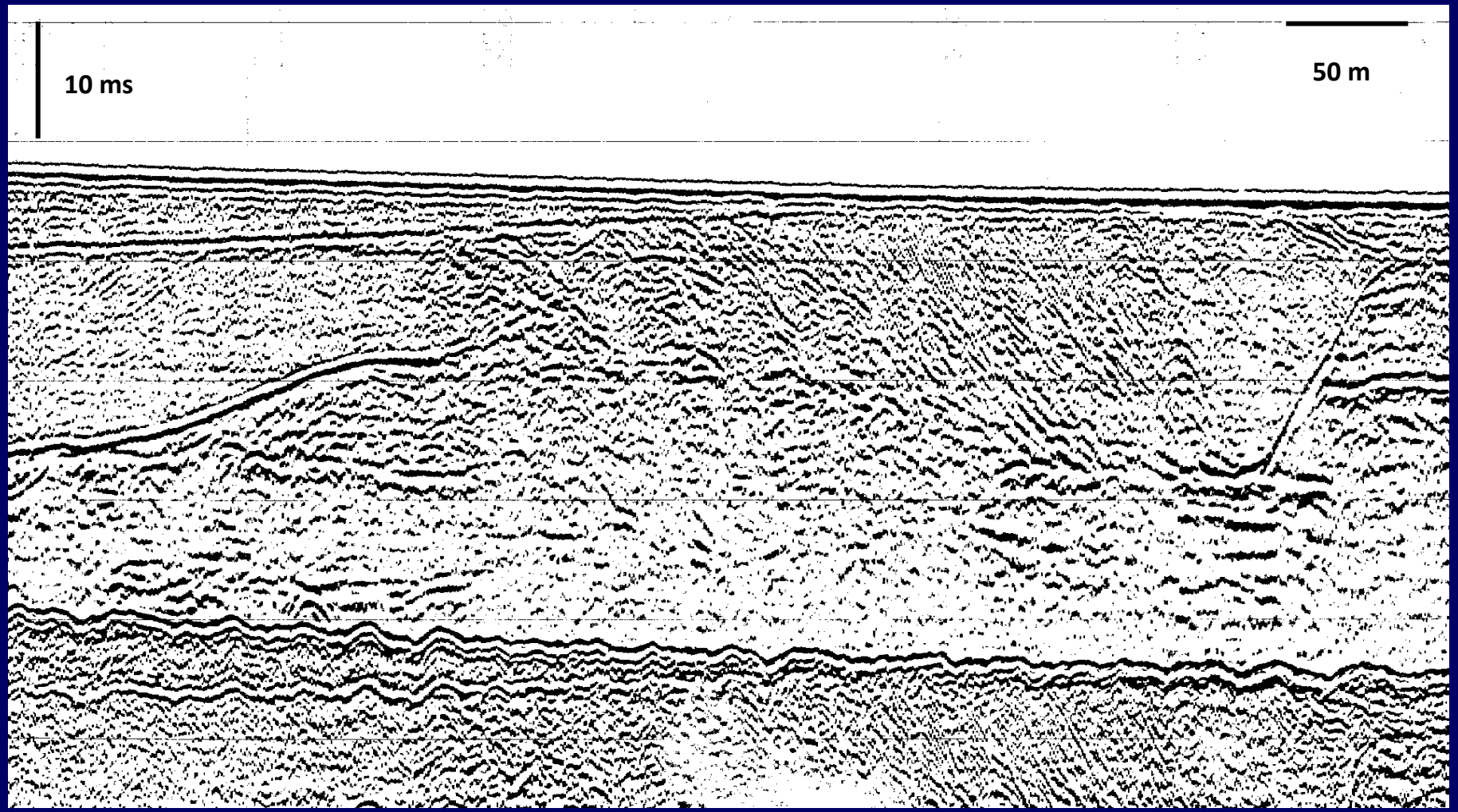
Typical frequency f_d: 0.5 to 1.5 kHz

Stored energy: 100-1000 joules
Typically 100 – 500 joule output

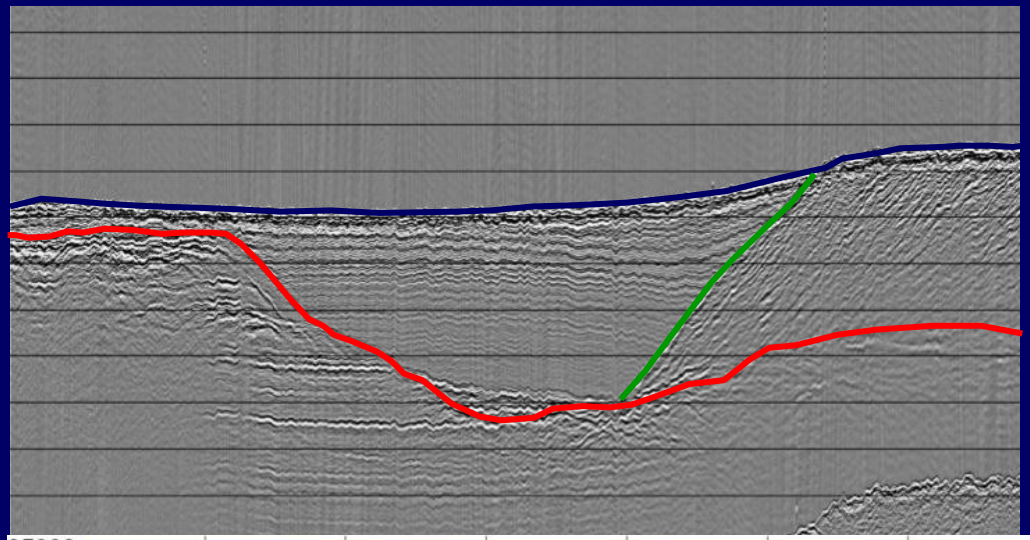
Pulse duration 100-200 μs

Vertical resolution: 25 – 50 cm
Penetration depths: 100 metres

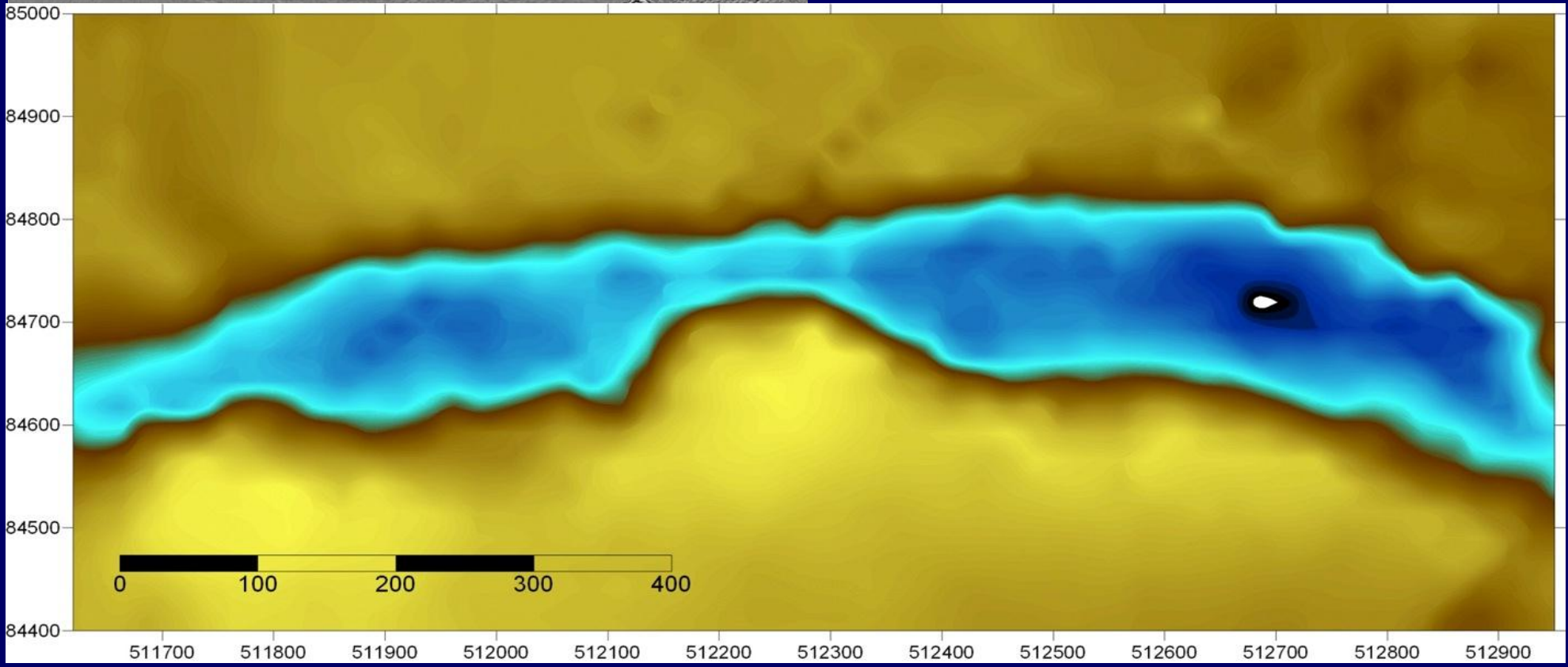
Classic Aggregate Industry Boomer Section



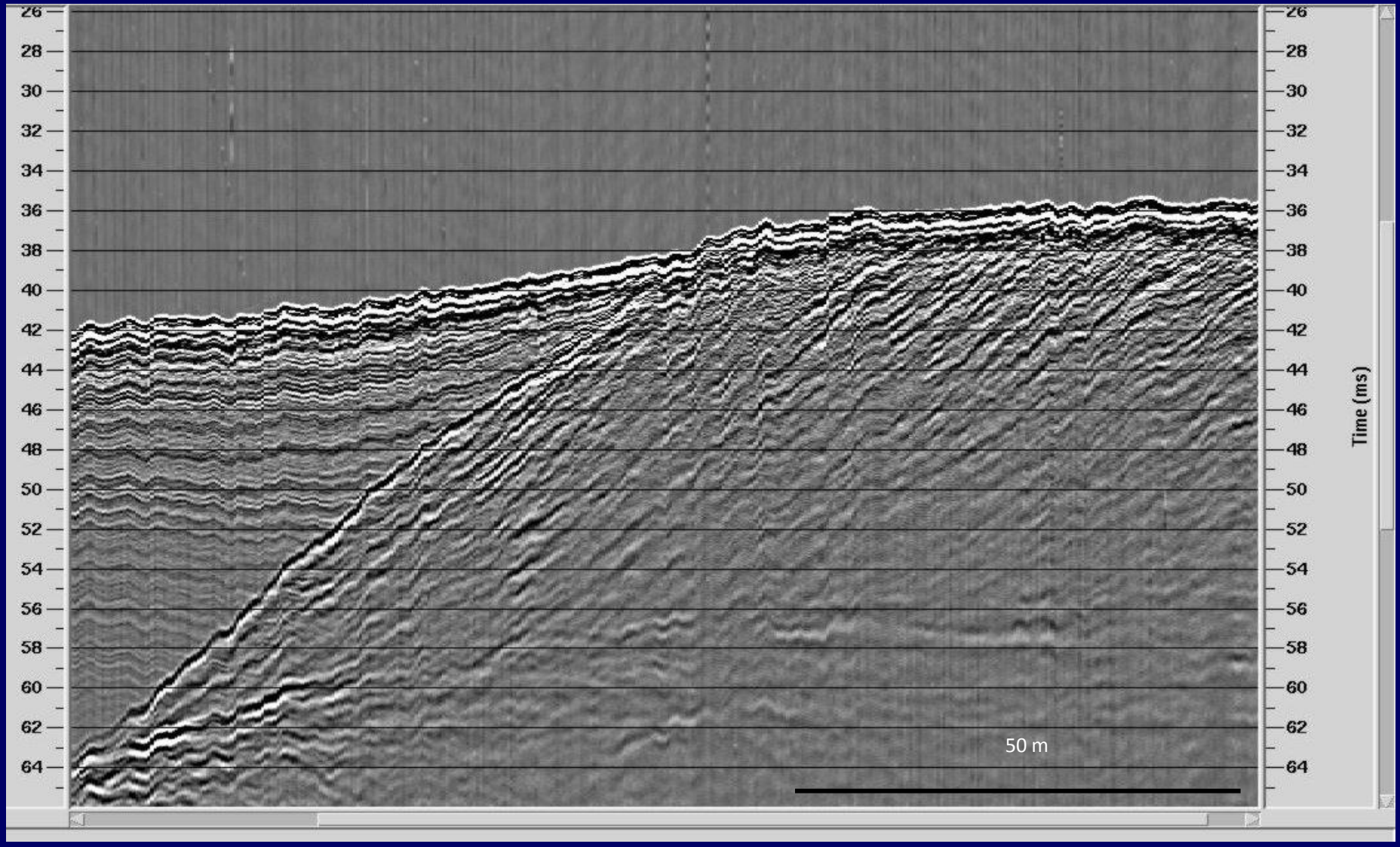
Courtesy Hanson Marine Ltd.

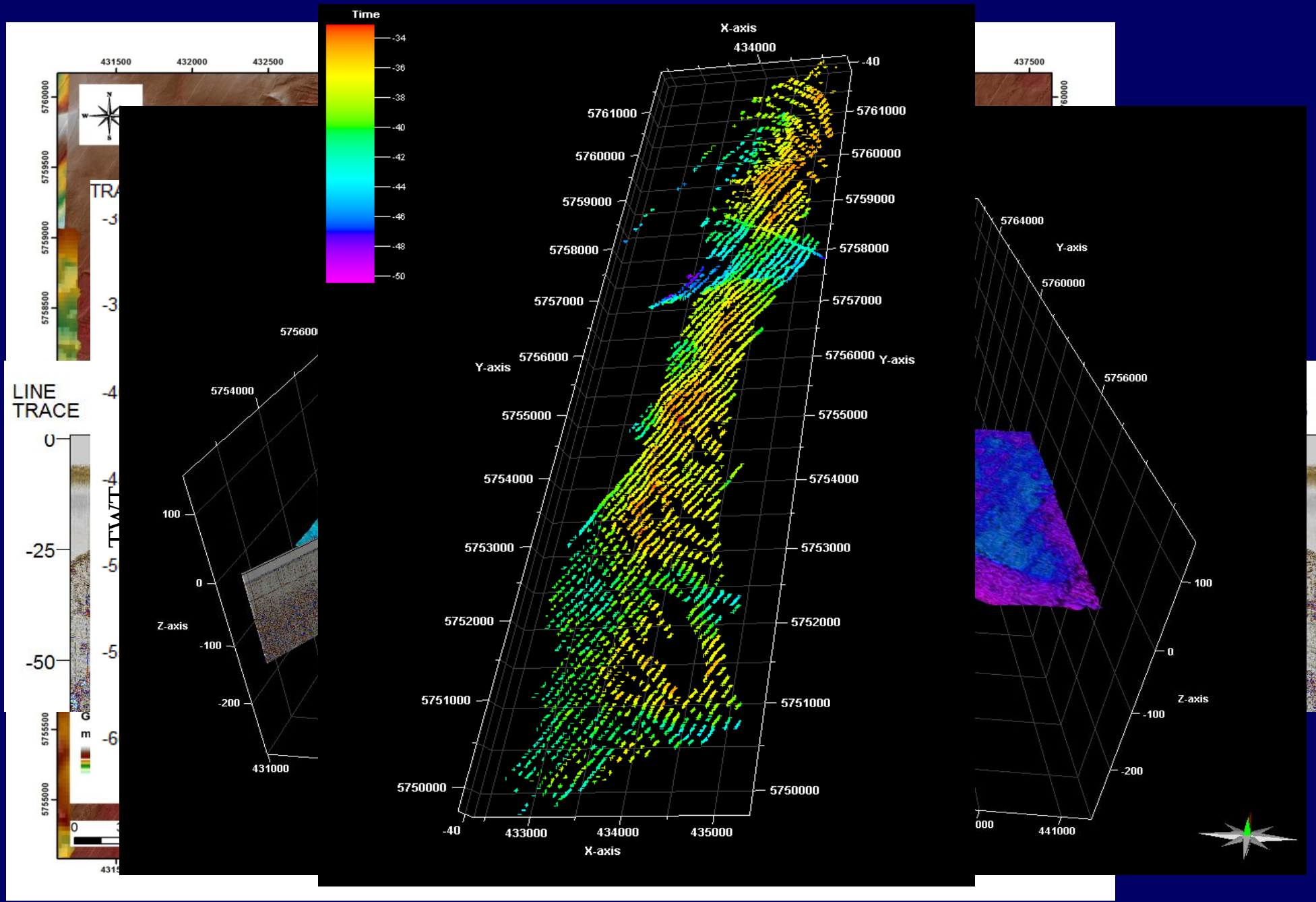


Boomer Data Offshore Arun River:
Wessex Archaeology, 2004 and
Dix et al., 2006 –
www.ads.adhs.ac.uk

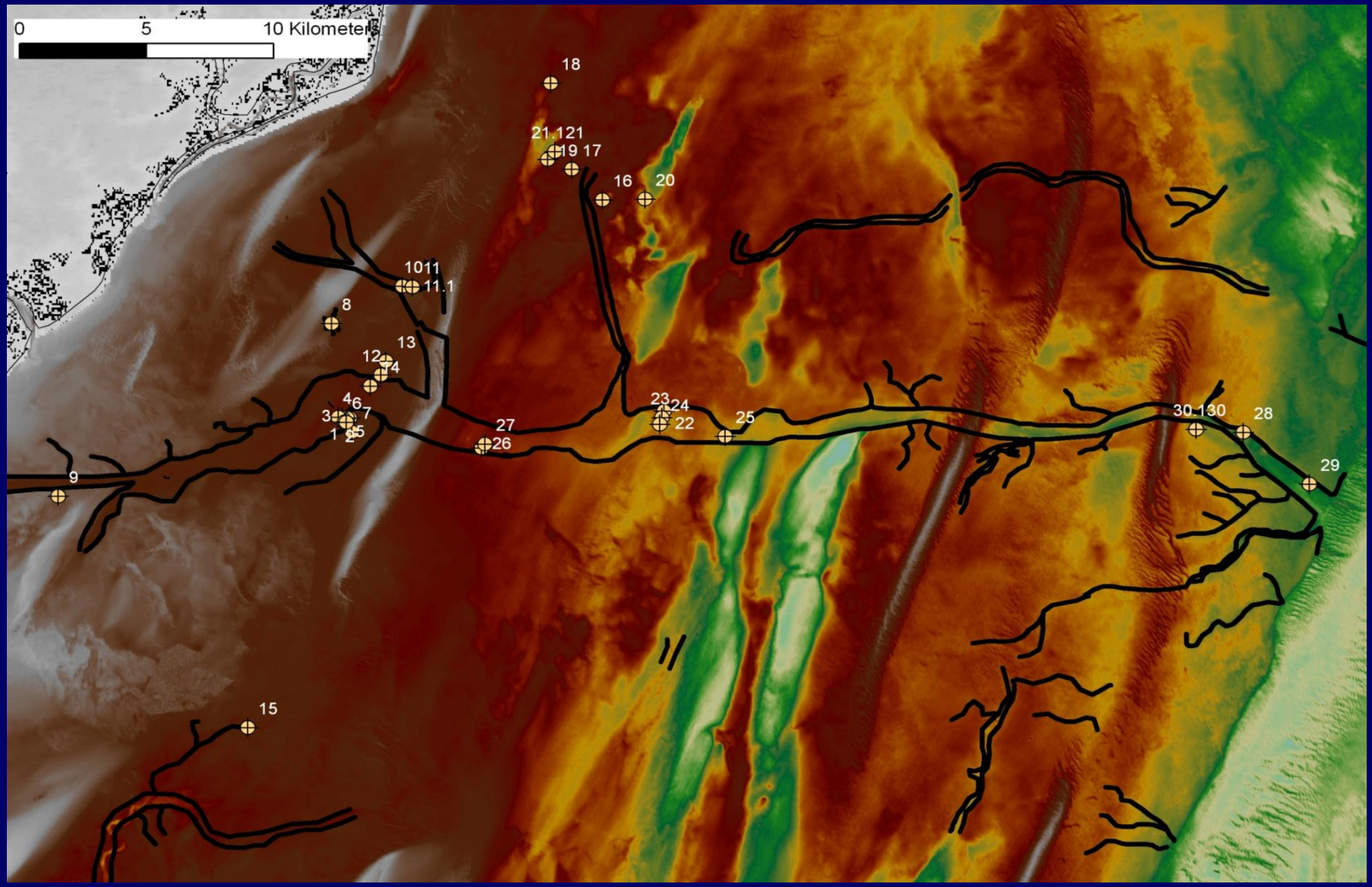


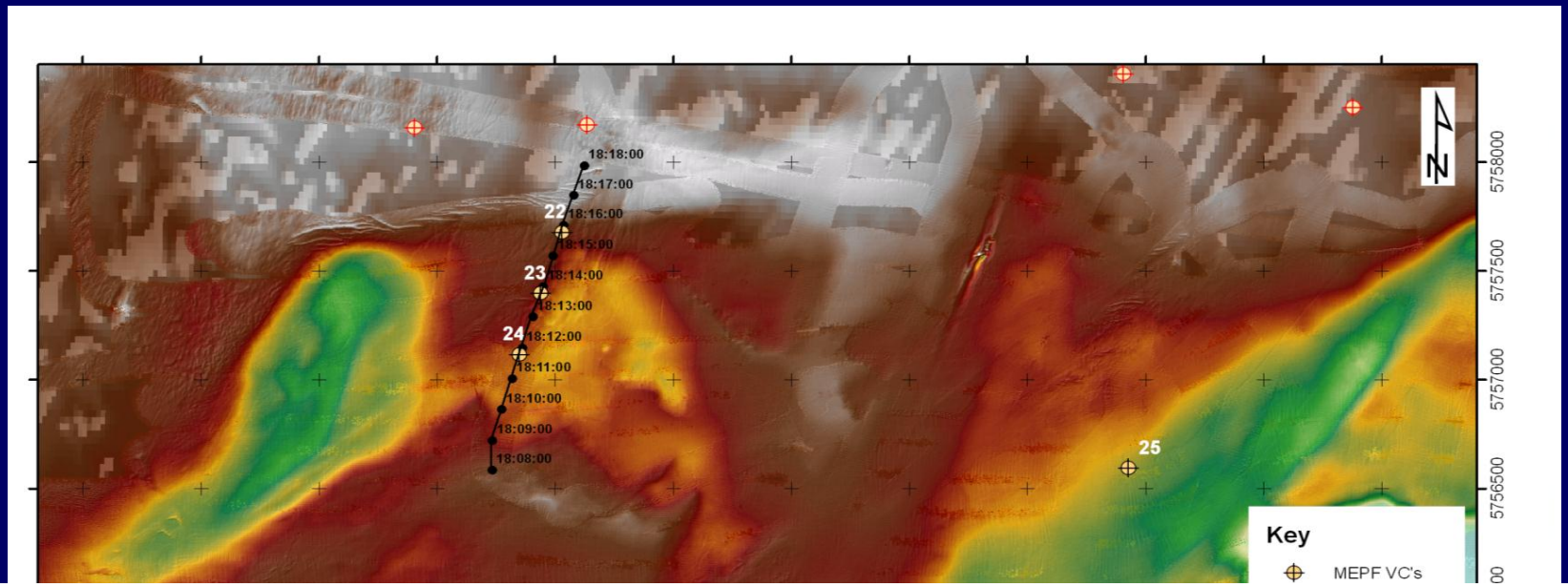
Internal structure at decimetre vertical resolution

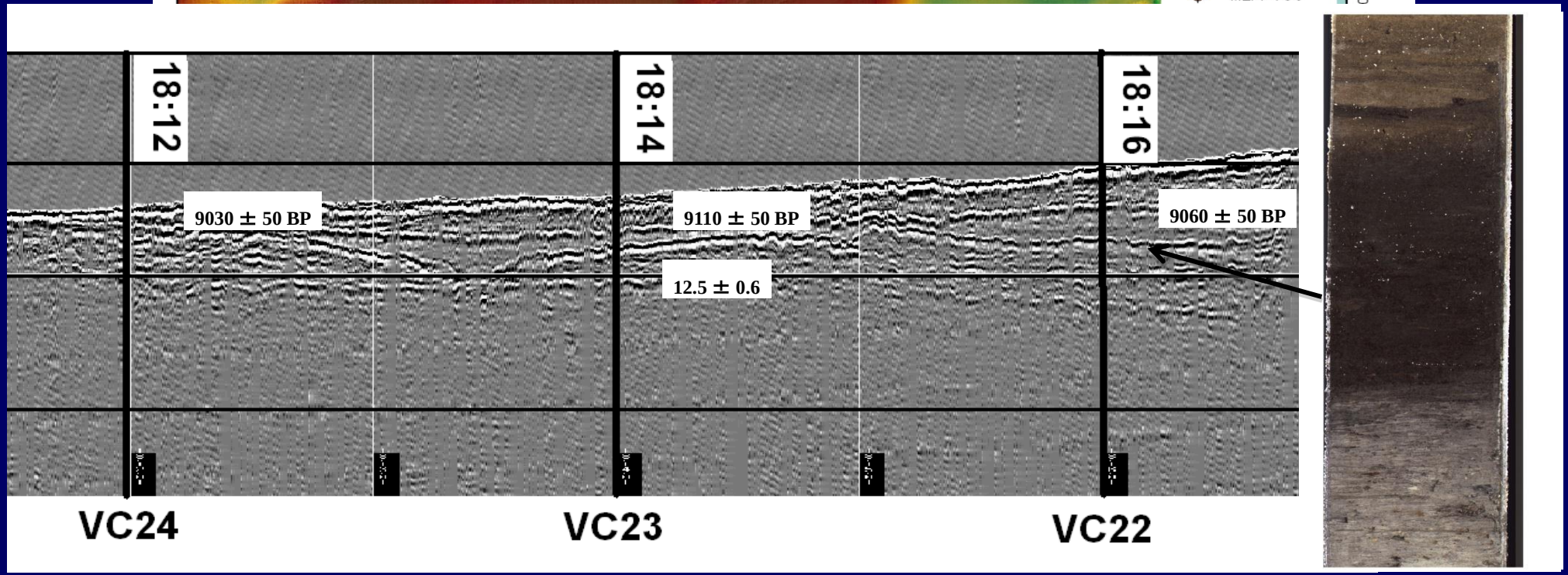



Time
-34
-36
-38
-40
-42
-44
-46
-48
-50
X-axis
434000
-40
5761000
5760000
5759000
5758000
5757000
5756000
Y-axis
5755000
5754000
5753000
5752000
5751000
5750000
433000
435000
LINE
TRACE
0
-25
-50
100
0
-100
-200
Z-axis
431000
5764000
441000

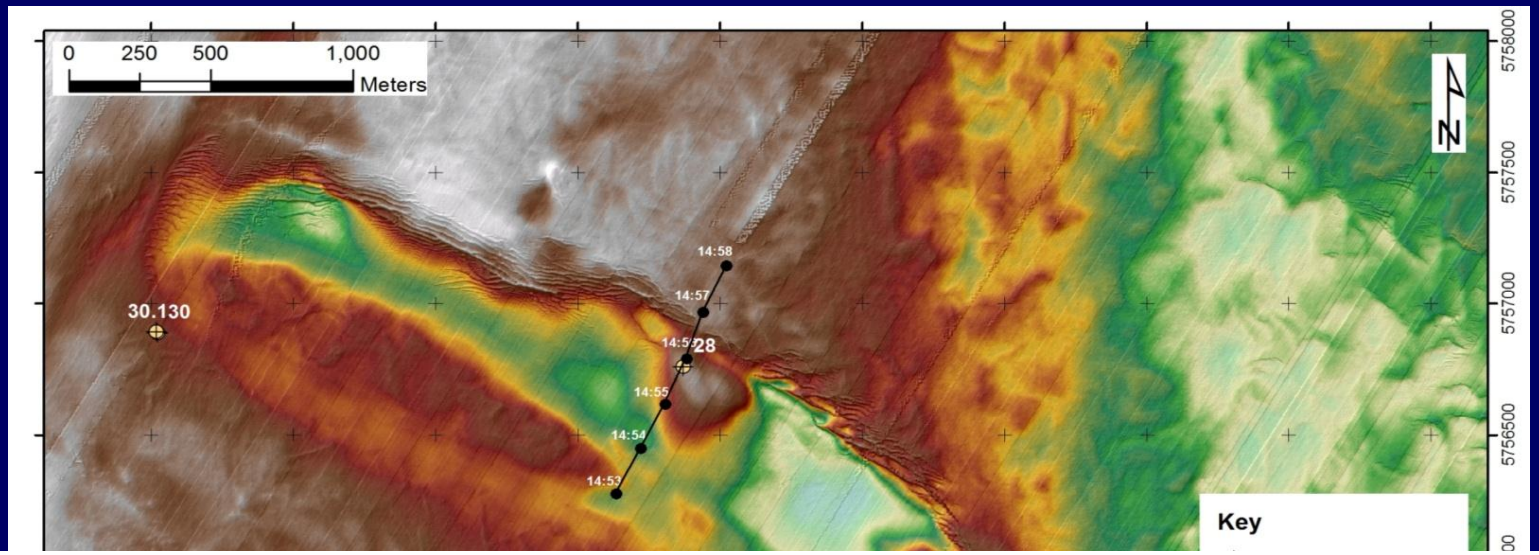
Acquisition of 30 Vibrocores

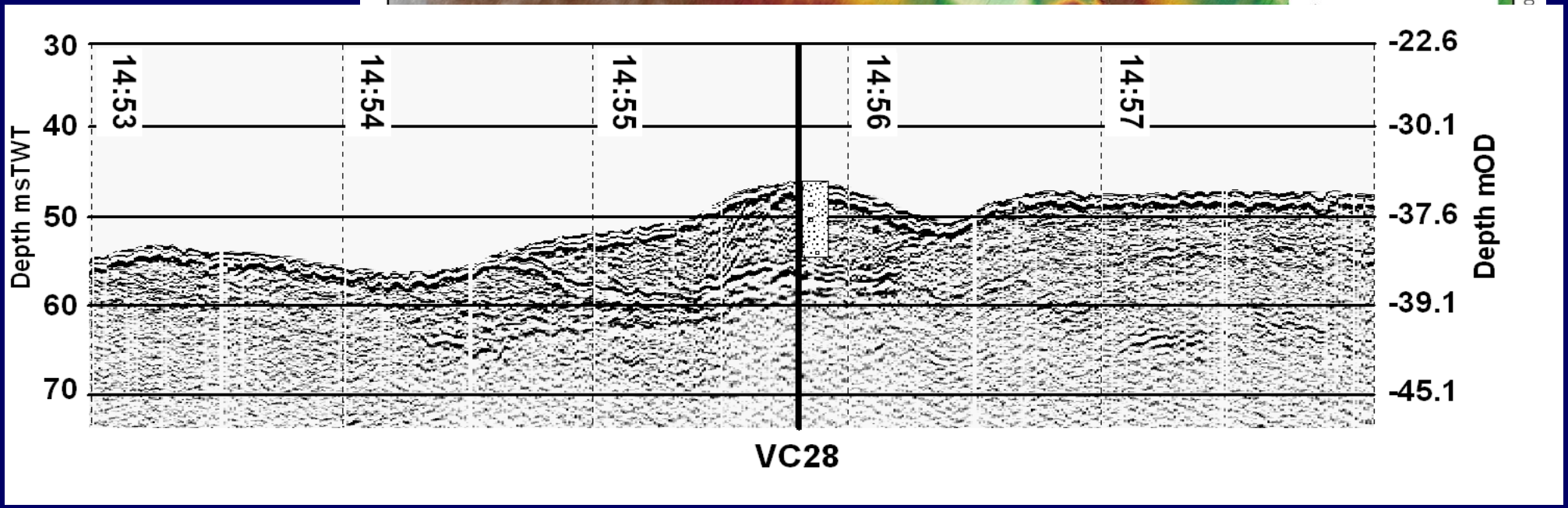



18:18:00
18:17:00
22
18:16:00
18:15:00
23
18:14:00
18:13:00
24
18:12:00
18:11:00
18:10:00
18:09:00
18:08:00
25
N
5758000
5757500
5757000
5756500
Key
MEPF VC's


18:12
18:14
18:16
9030 ± 50 BP
9110 ± 50 BP
9060 ± 50 BP
12.5 ± 0.6
VC24
VC23
VC22

Lithological Log and Seismics VC28

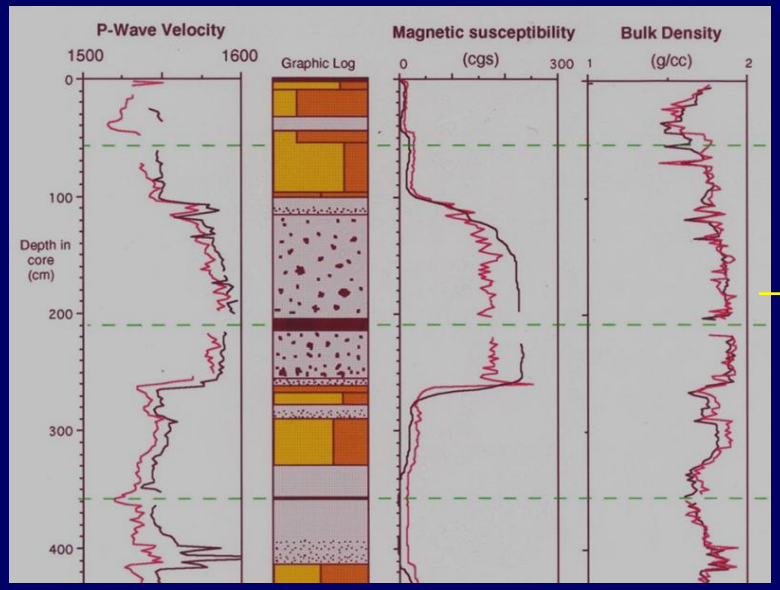


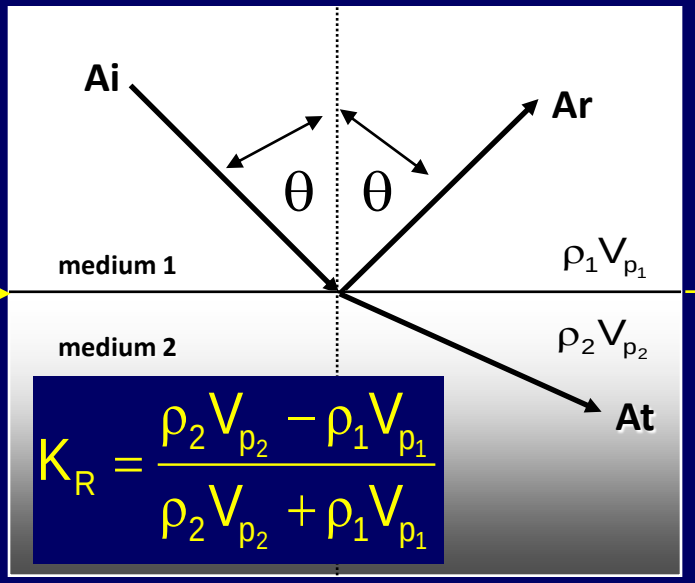


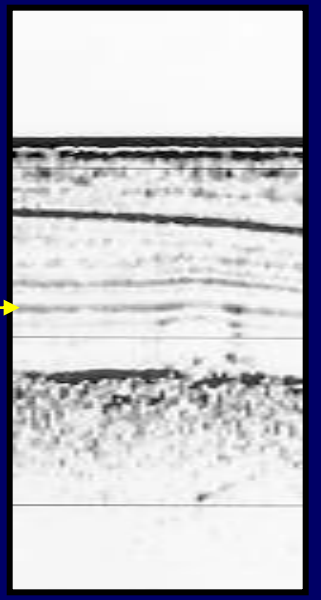
Using physical and acoustic data: synthetic seismograms

One can model sub-surface profile via series of reflections from a series of sediment layers, i.e. synthetic seismogram

Information for these seismograms can be obtained from physical and acoustic properties of cores as reflection coefficient depends on density and velocity of sediment







Porosity and bulk density

Measured through Multi-Sensor Core logger (MSCL).

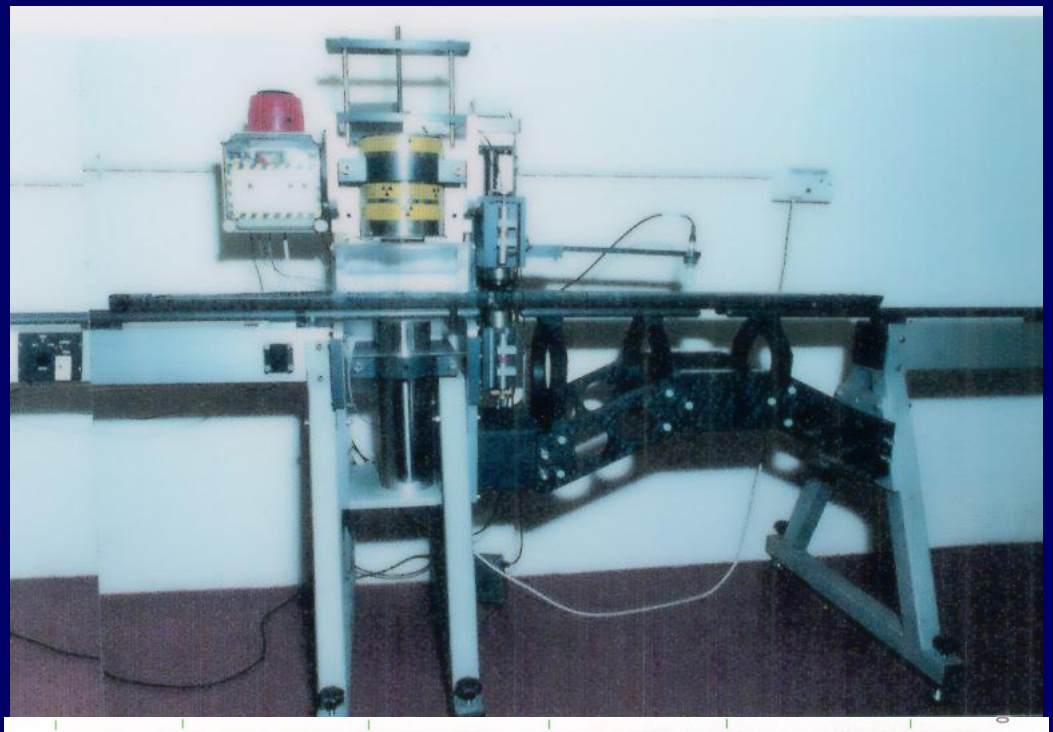
Can examine split or unsplit cores.

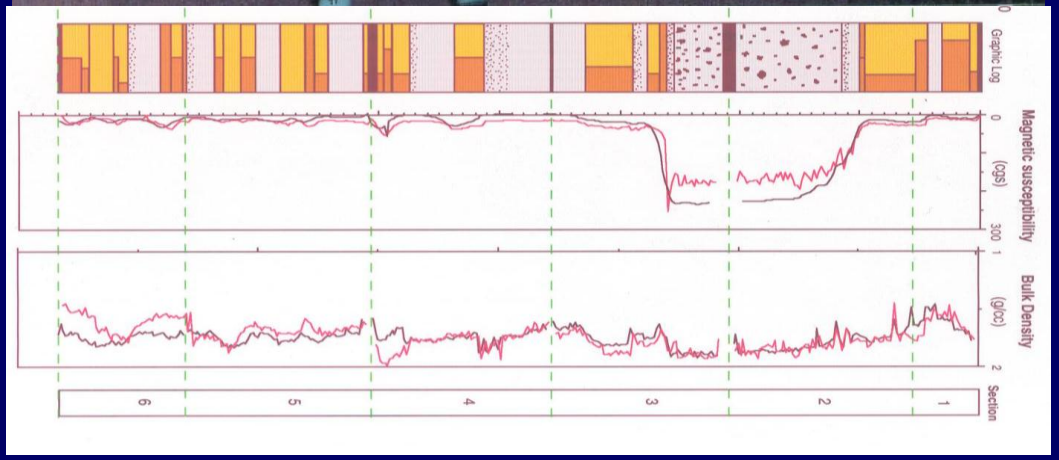
Measures attenuation of gamma rays through sediment, with comparison with calibration material required to obtain density.

Porosity (*n*) subsequently obtained from

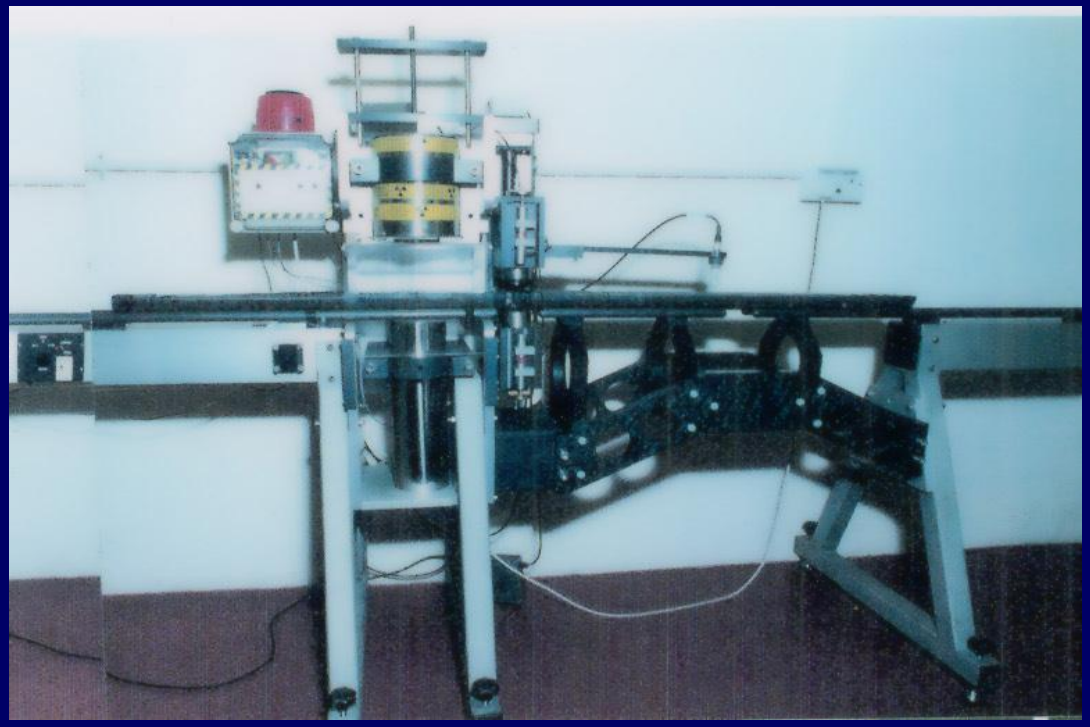
$$\rho = n.\rho_w + (1-n).\rho_r$$

Using known density of grains ρr and density of water ρw





Laboratory techniques: Compressional Wave Velocity



In addition to density MSCL can measure compressional wave velocity
Uses cross-comparison of transmission of 400 kHz pulse through sediment core and calibration water based core