DEFENCE R&D DÉFENSE

An approximate relationship between water depth and geoacoustic properties for application in sonar performance prediction in uncertain environments

John Osler, Dale Ellis, and David Chapman

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Recherche et développement pour la défense Canada

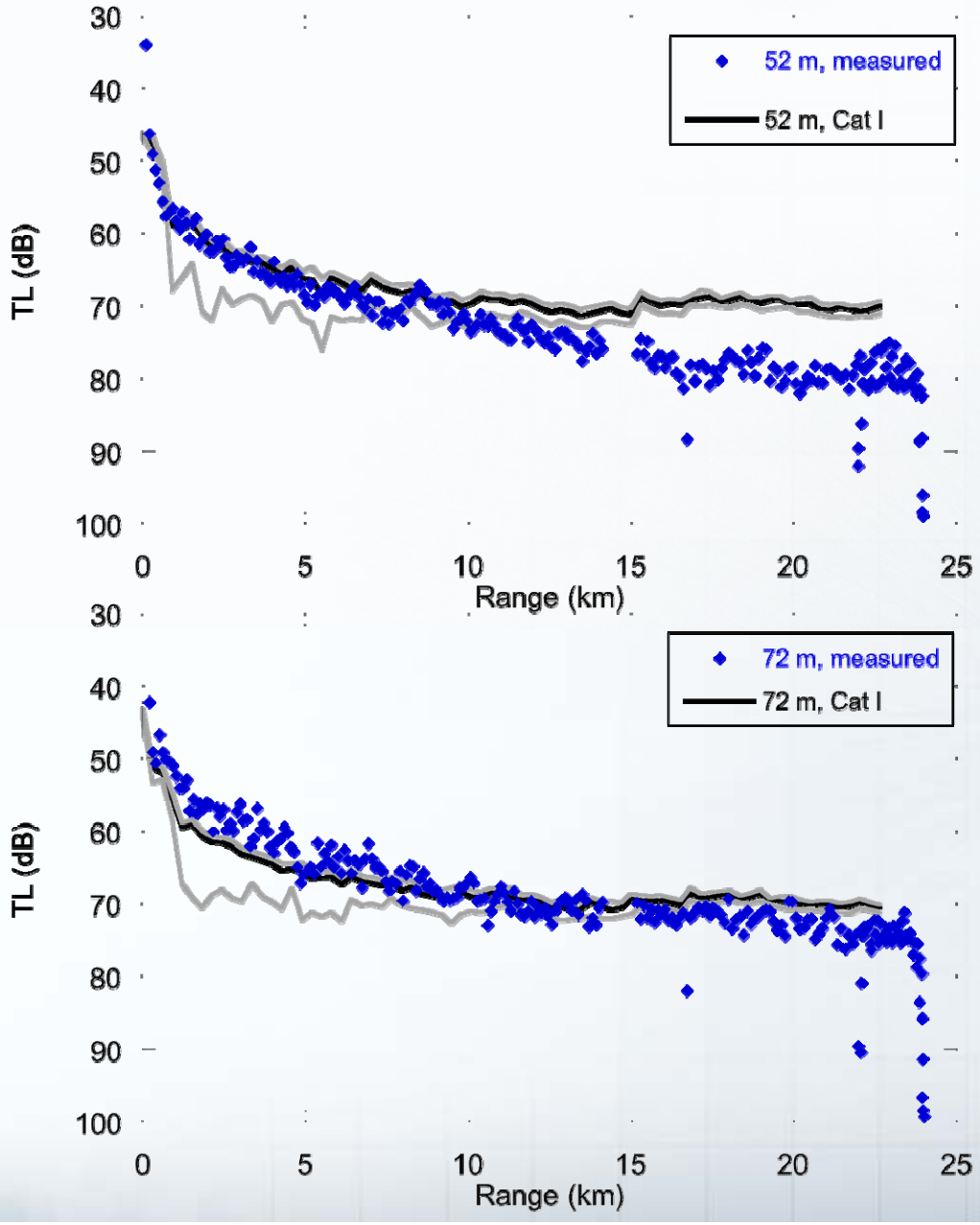
Canada

One Statement of the Problem

"…the Allied Environmental Support System [once a NATO standard tool for sonar performance prediction] is generally deemed unsatisfactory, **due mainly to inaccurate environmental inputs from the NSODB** [NATO Standard Oceanographic Data Base]. The **bottom-loss information is found to be the weakest link**, but also bathymetry and sound velocity profile information can have adverse effects…"

Ferla and Jensen [2002]

Transmission Loss: Initial Model & Data Comparison



From Pecknold et al.

- Sensitivity to bottom properties is high for the shallower receiver
- TL estimates are poor when relying on an historical (global) database

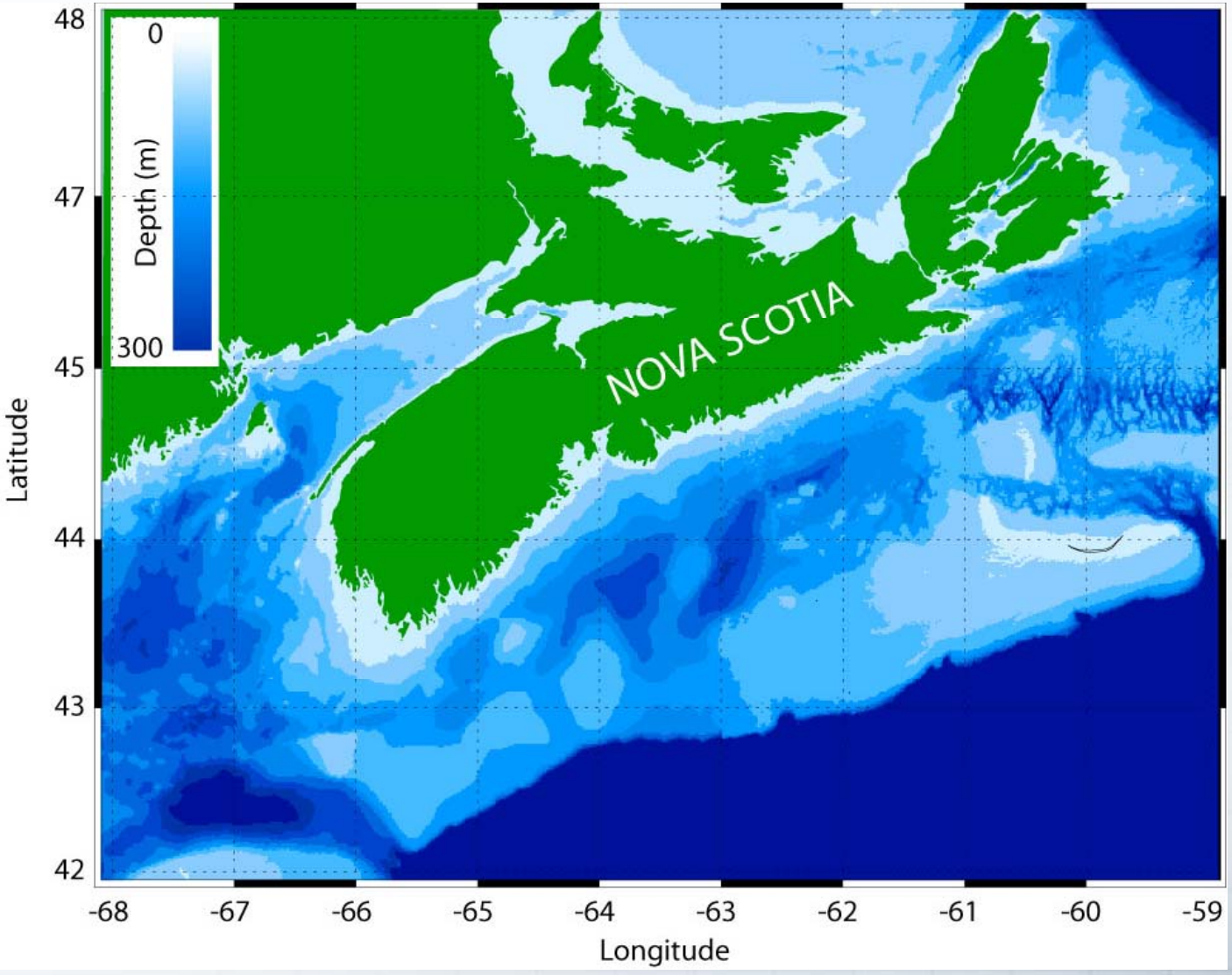
Proposed Approach

- Thiele and Tielbürger [1997] proposed a hierarchy of approaches:
  1. Estimate bottom properties by bathymetry
  2. Use navigational maps or oceanographic-current maps and sporadic information
  3. Dedicated maps of surficial sediments
  4. Direct reflectivity or transmission loss measurements
- In this research, we investigate the correlation between ‘1’ and ‘3’ to develop an empirical relationship, and compare with ‘4’

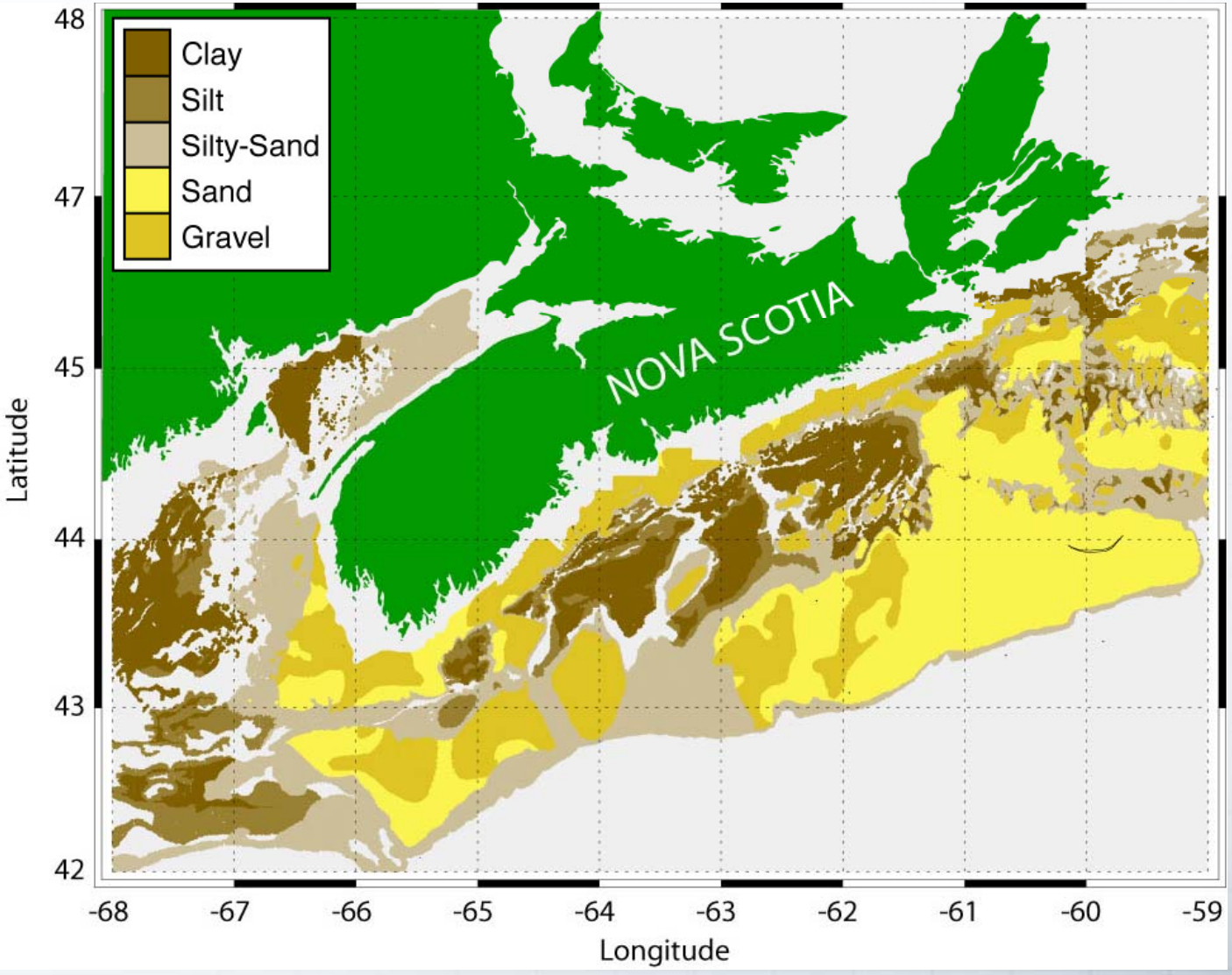
Applicability

- Once established, this relationship permits reasonable geo-acoustic parameter estimates in the absence of any information other than water depth (REA Cat. I or II)
- Limitations:
  - Location specific but basic tenets likely valid for other formerly glaciated continental margins
  - Suitable for frequencies greater than ~ 1 kHz, with bottom interaction limited to a few metres or less
- Analysis enabled by the development of a GIS database, and motivated by a client requirement

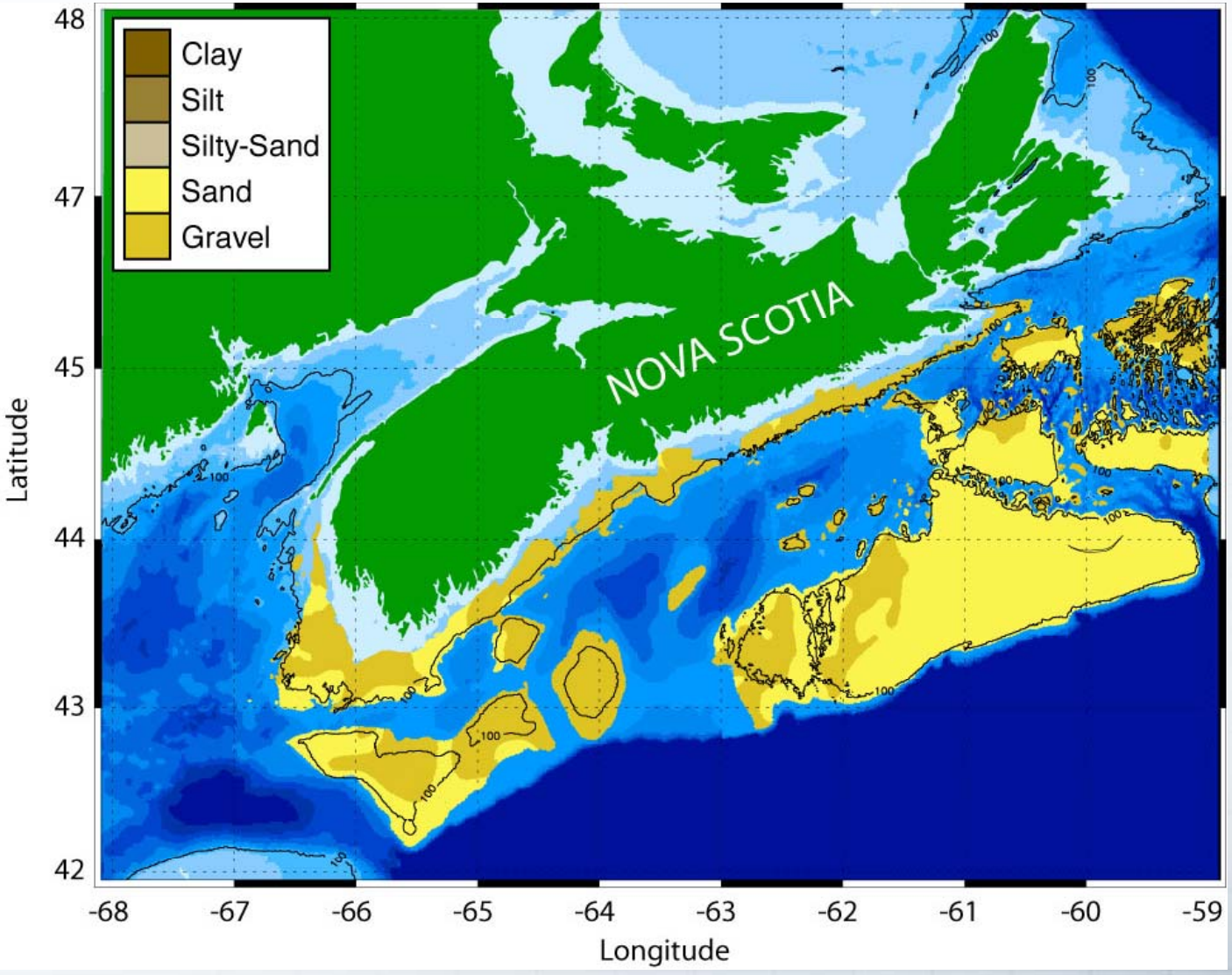
Scotian Shelf - Bathymetry



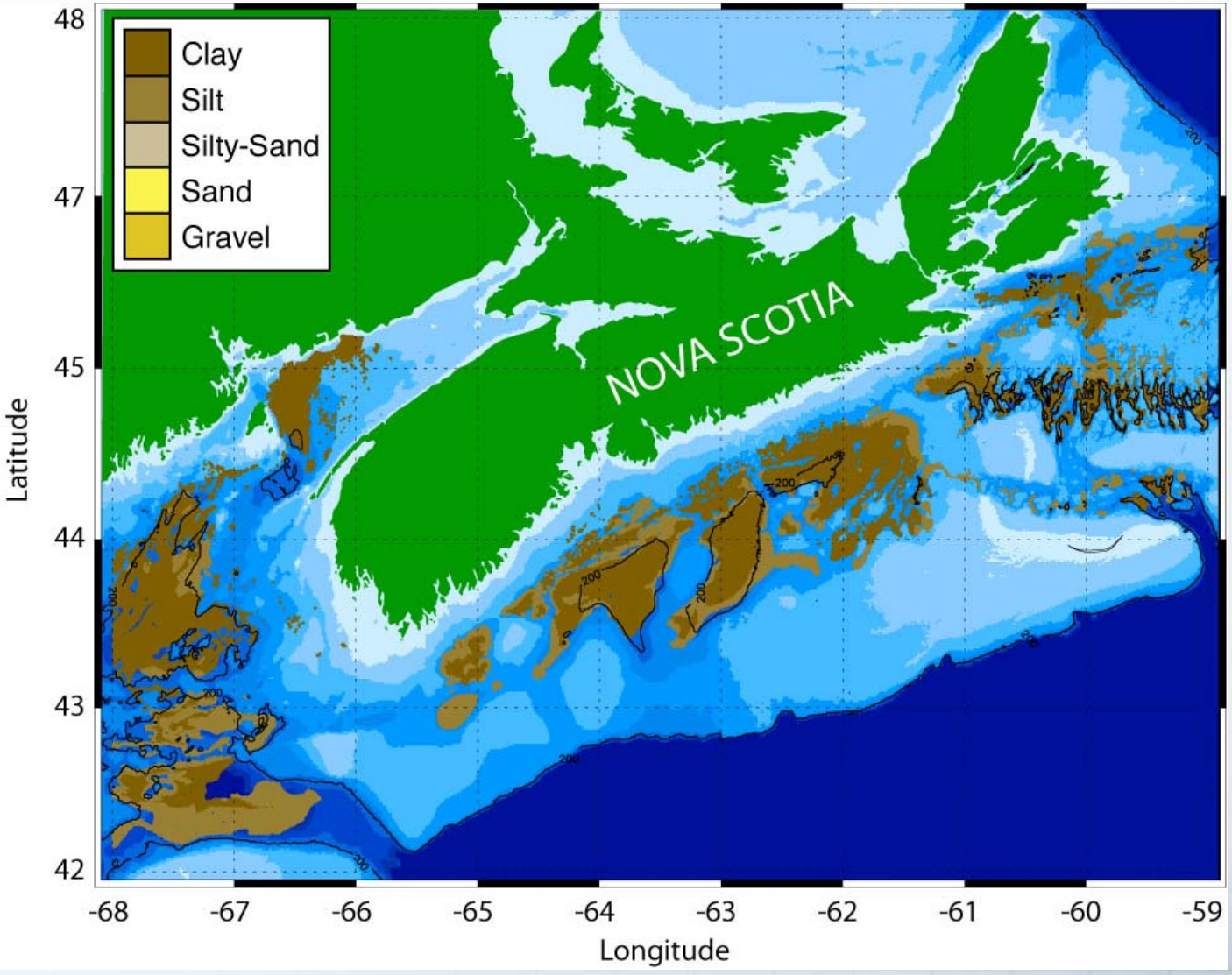
Scotian Shelf – Surficial Geology



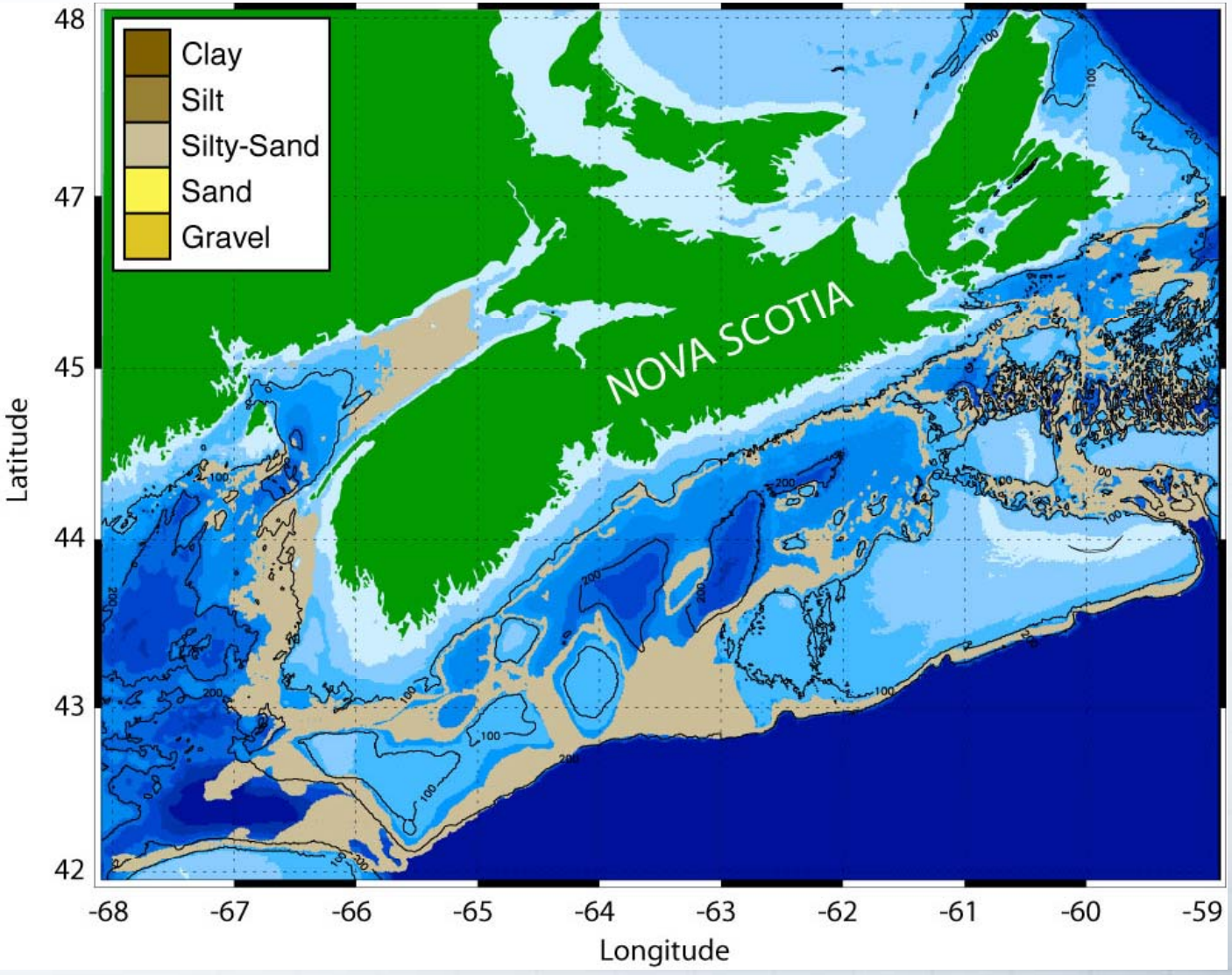
Scotian Shelf – Sand & Gravel Areas



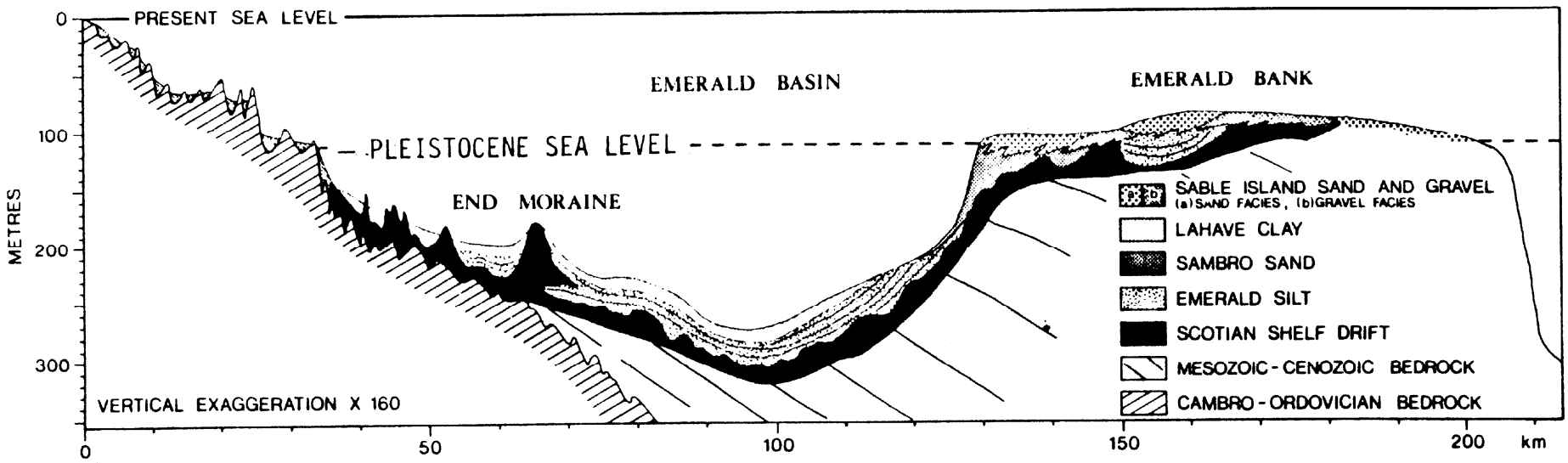
Scotian Shelf – Clay & Silt Areas



Scotian Shelf – Sandy Silt Areas

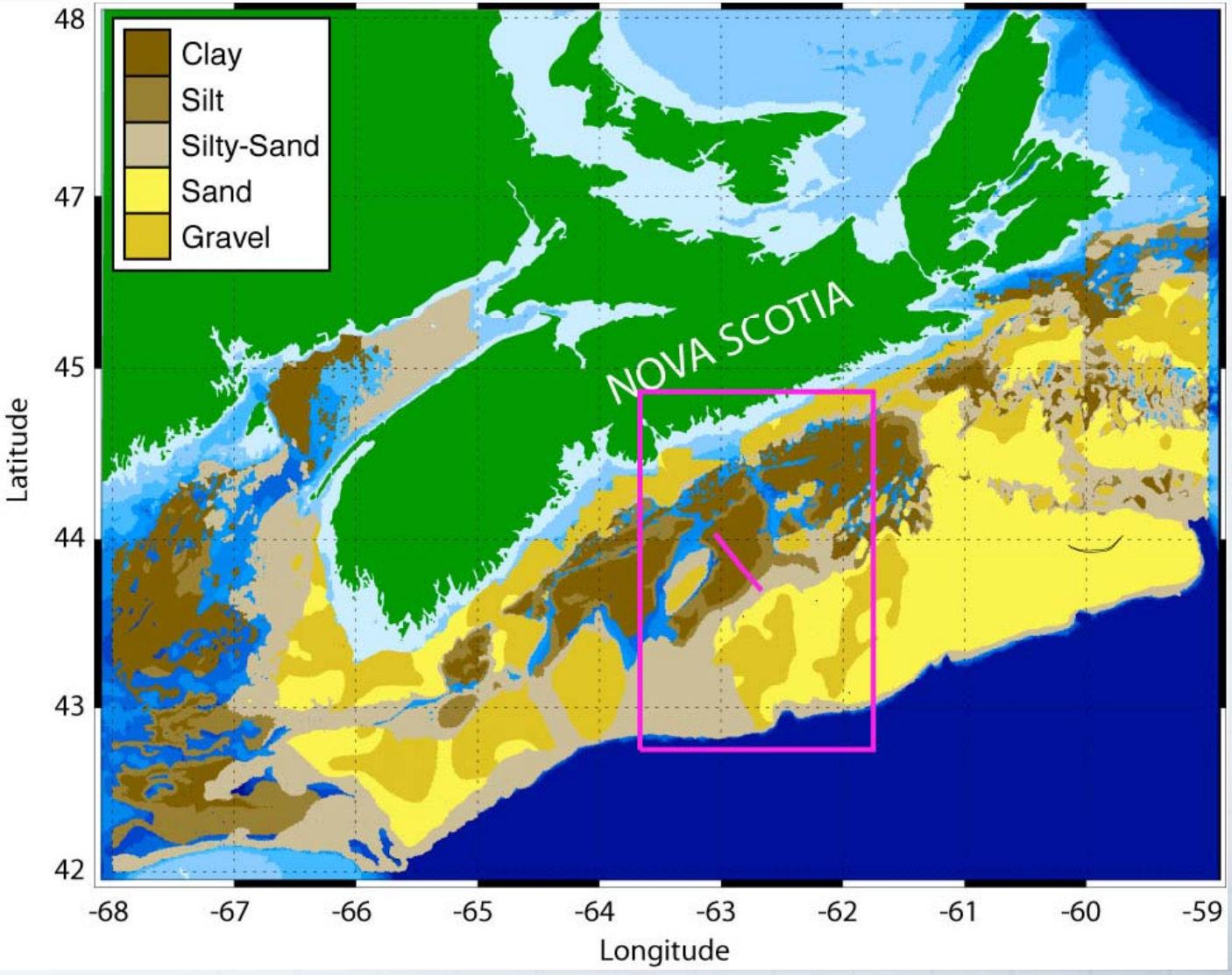


Scotian Shelf: Cross-Section

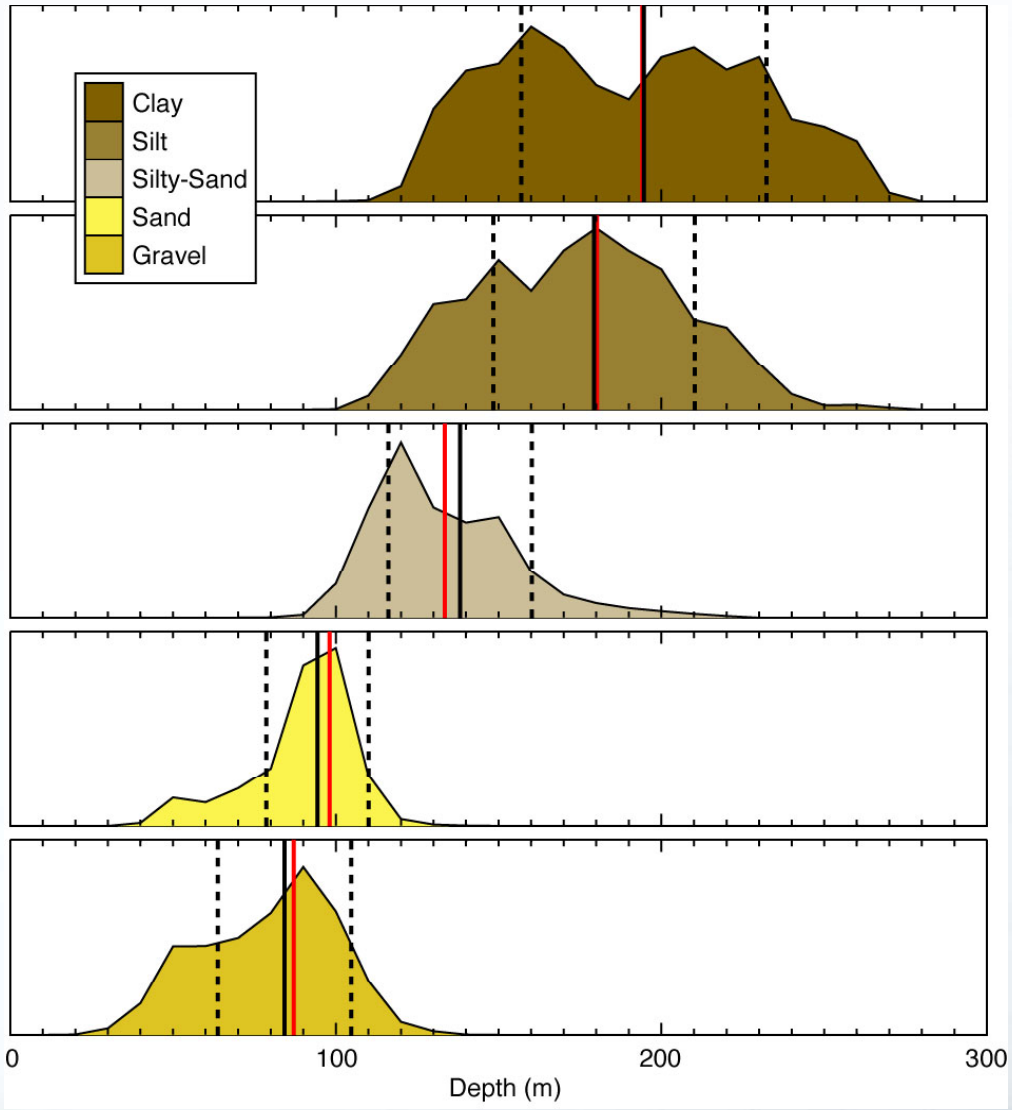


From King et al. [1983]

Scotian Shelf – Detailed Study Area



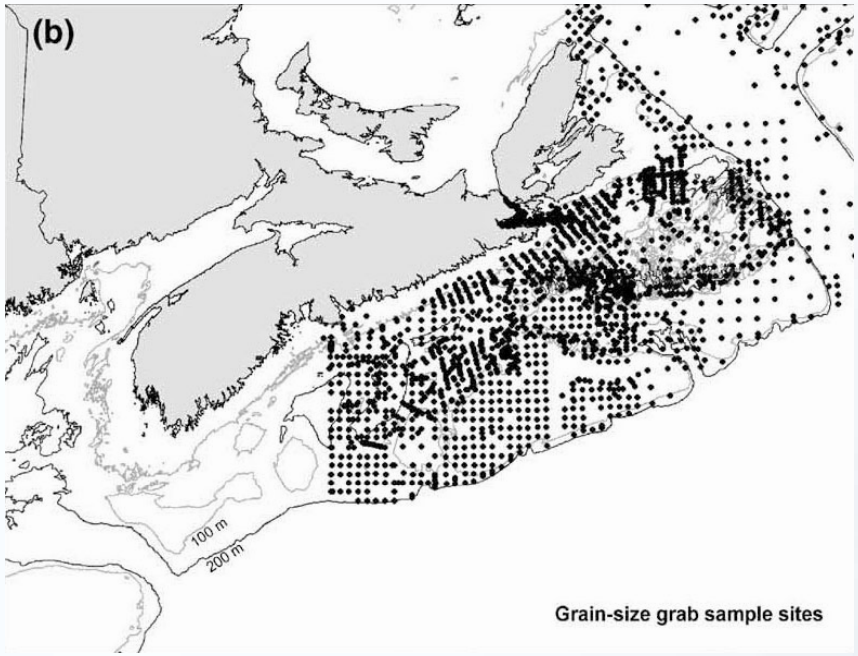
Histograms – Water Depth & Sediment Type



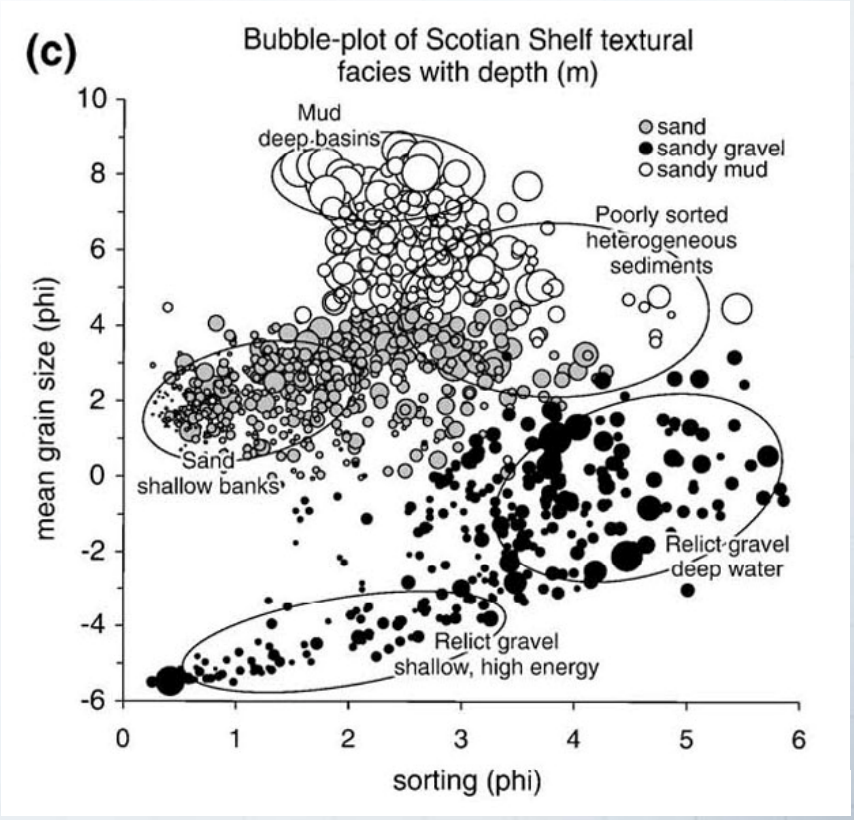
- Sediment type is related to water depth
- Distributions are bimodal or polymodal(as on many continental shelves with a glacial signature)

Grain Size Information

Grab Sample Sites

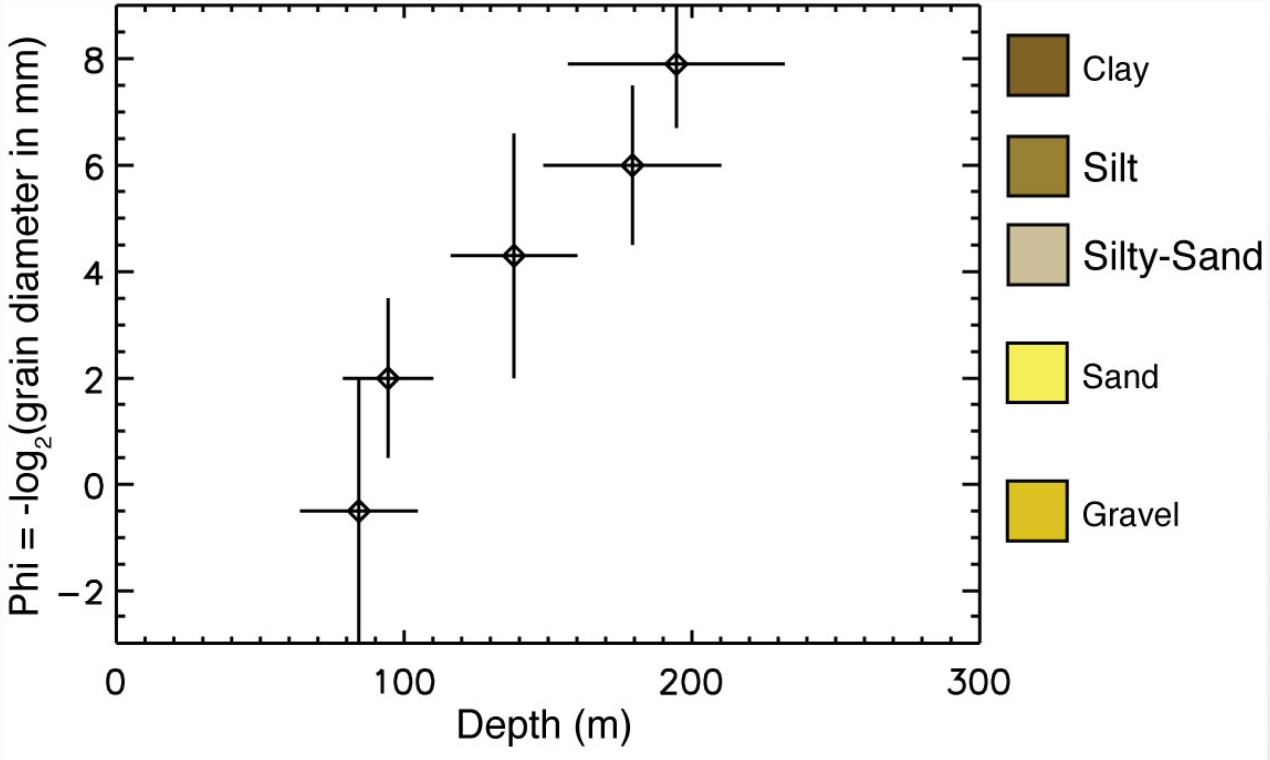


‘Facies’ Discrimination



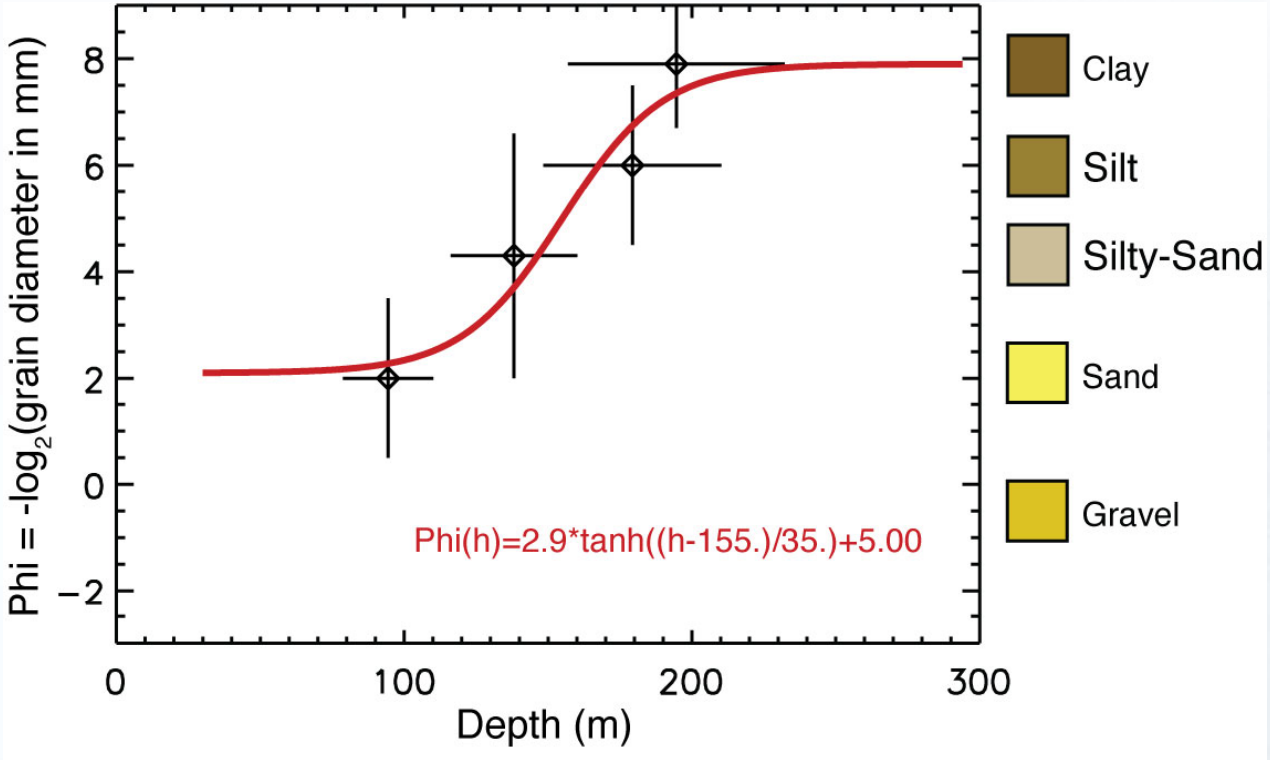
Orpin and Kostylev [2006]

Grain Size vs Water Depth



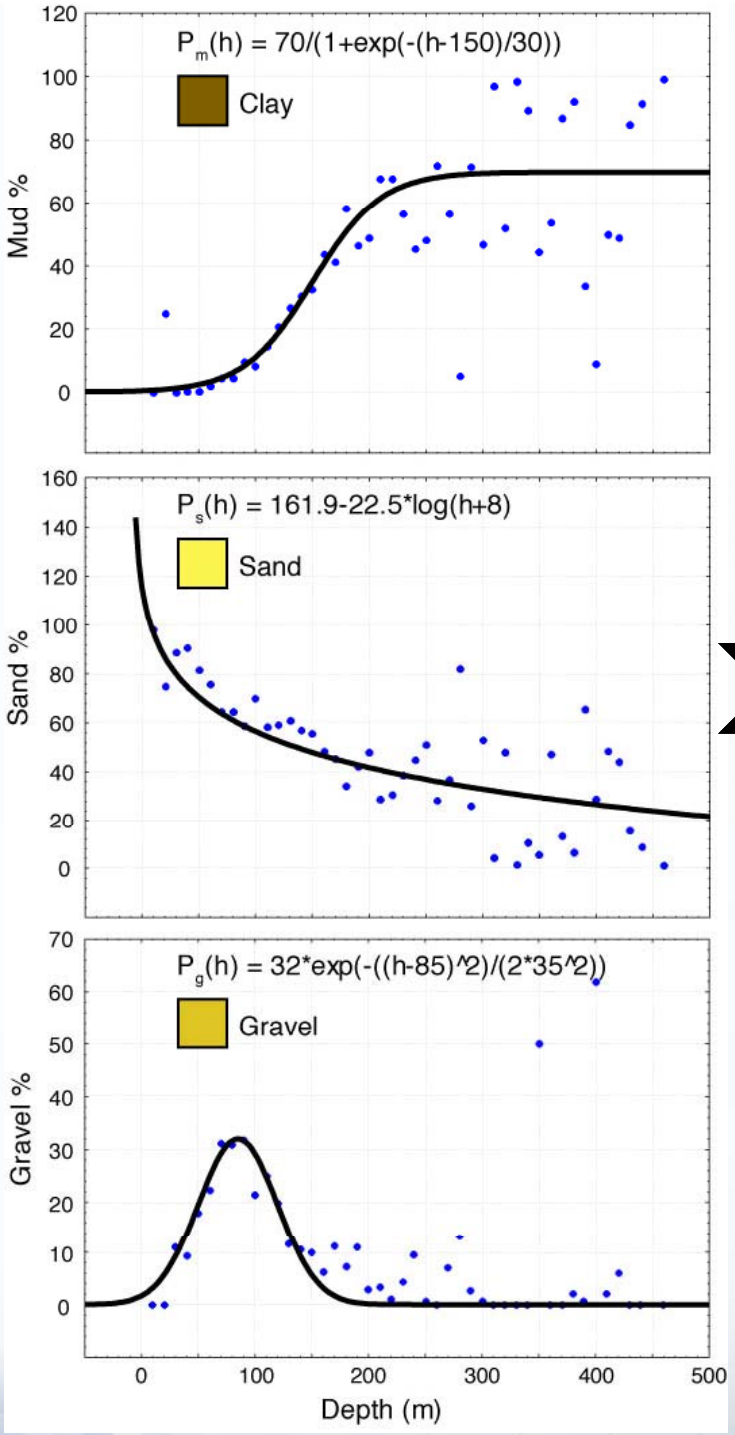
- Mean water depth from histograms
- Mean grain size from analysis of grabs

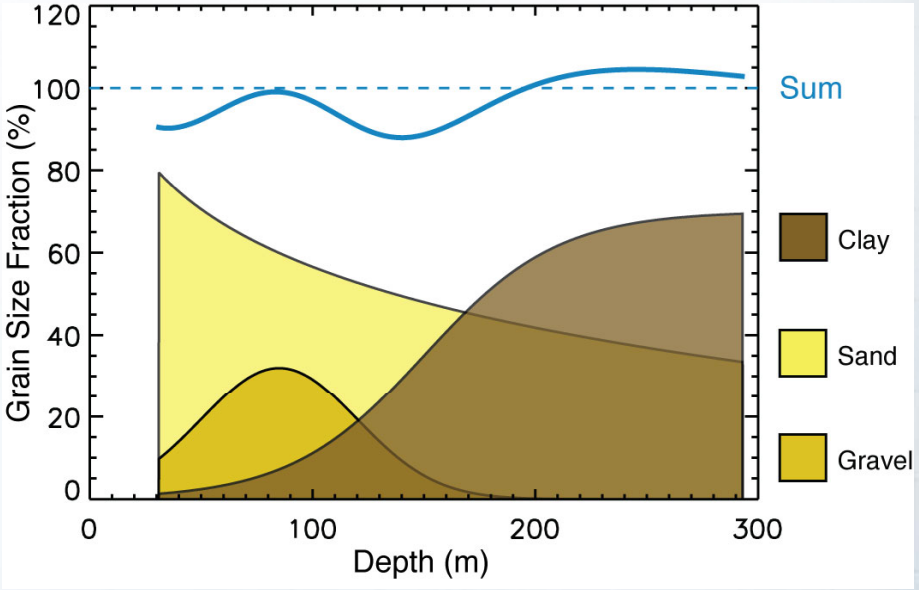
Grain Size vs Water Depth



- Ignore gravel for the moment
- Fit hyperbolic tangent function

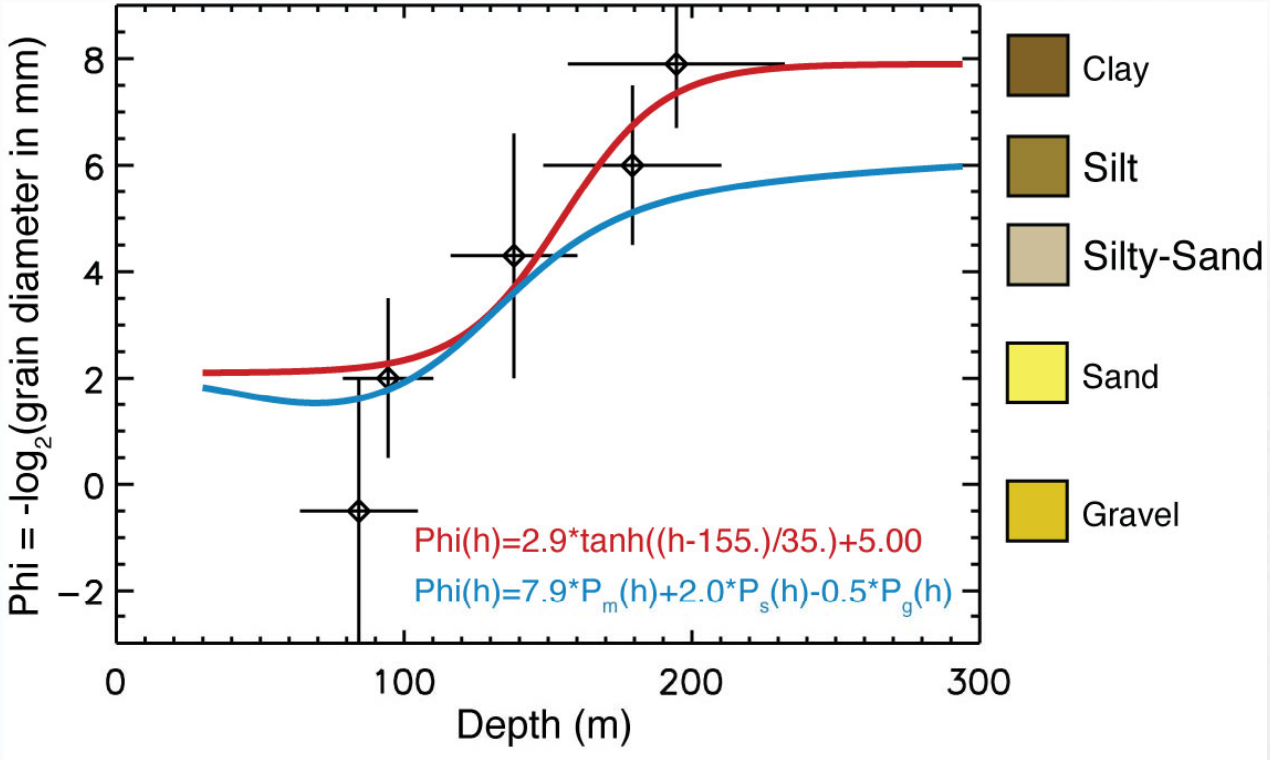
An Alternate Formulation to include the Gravel





Furlong et al. [2006]

Grain Size vs Water Depth



Grain Size and Geoacoustic Properties

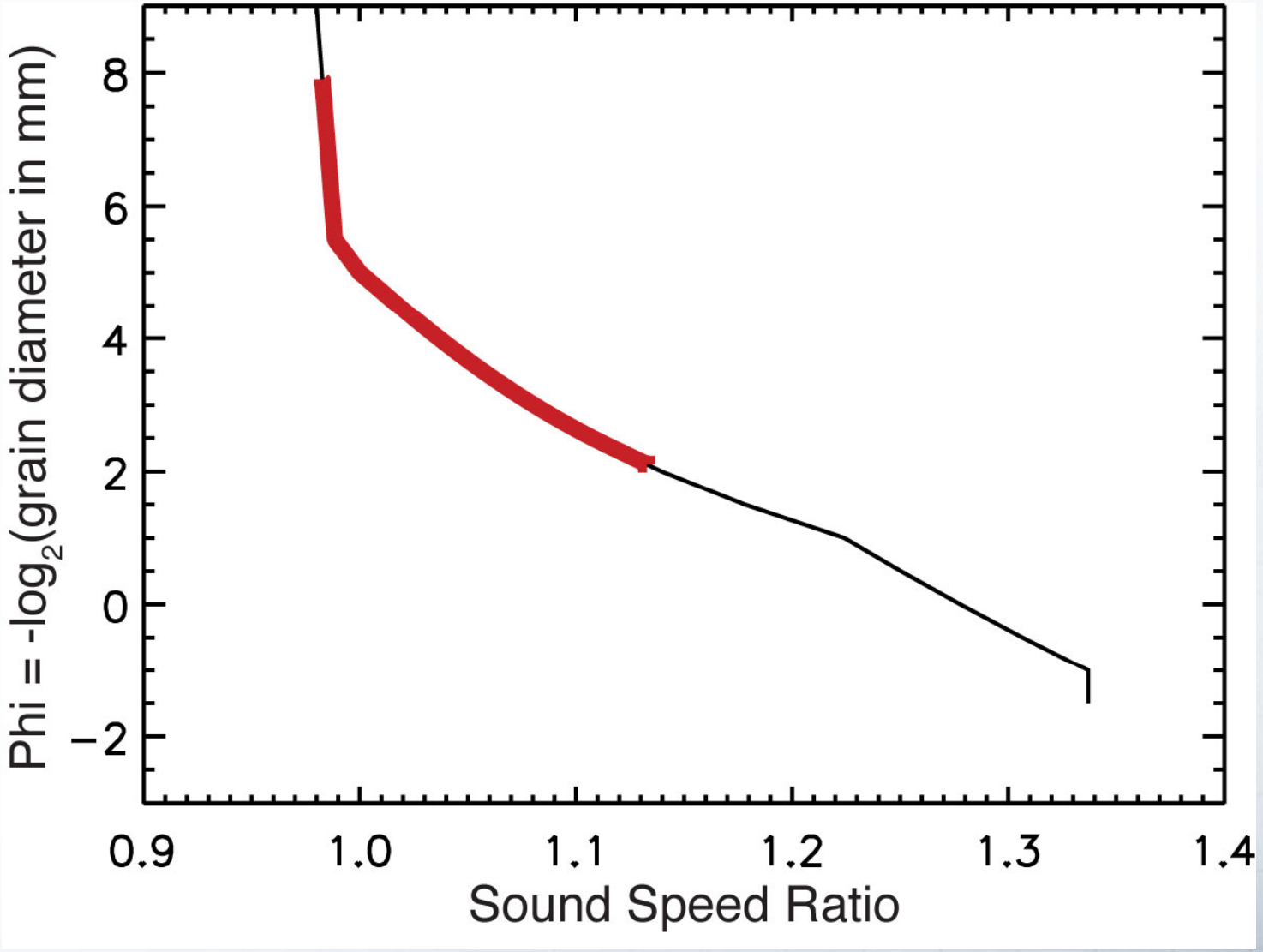
- The APL-UW Environmental Handbook [1994] gives simple expressions for the density, sound speed ratio, and attenuation as a function of the grain size (Mz) in phi units from -1 to 9.
  - Attenuation identical to Hamilton [1972]
  - Density and sound speed ratios are modified versions of Hamilton and Bachman [1982] and use shallow water data rather than deep water data

$$c_r = \begin{cases} 1.2778 - 0.056452M_z + 0.002709M_Z^2 & -1.0 \le M_z < 1.0 \\ 1.3425 - 0.1382798M_z + 0.0213937M_z^2 - 0.0014881M_z^3 & 1.0 \le M_z < 5.3 \\ 1.0019 - 0.0024324M_z & 5.3 \le M_z \le 9.0 \end{cases}$$

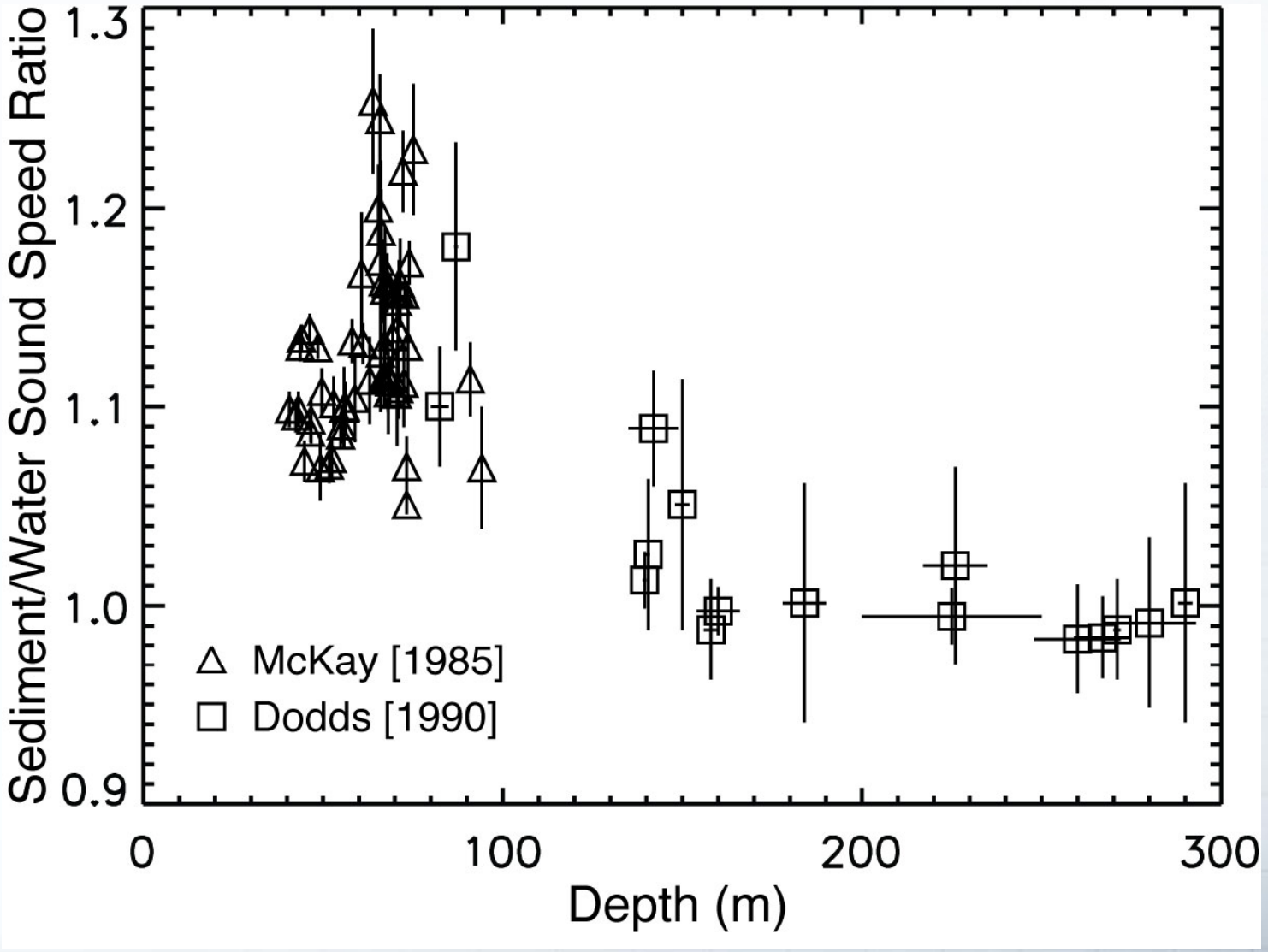
$$\rho = \begin{cases} 2.3139 - 0.17057M_z + 0.007797M_z^2, & -1.0 \le M_z < 1.0 \\ 3.0455 - 1.1069031M_z + 0.2290201M_z^2 - 0.0165406M_z^3, & 1.0 \le M_z < 5.3 \\ 1.1565 - 0.0012973M_z, & 5.3 \le M_z \le 9.0 \end{cases}$$

$$\alpha_2 = \begin{cases} 0.4556 & -1.0 \le M_z < 0.0 \\ 0.4556 + 0.0245M_z & 0.0 \le M_z < 2.6 \\ 0.1978 + 0.1245M_z & 2.6 \le M_z < 4.5 \\ 8.0399 - 2.5228M_z + 0.20098M_z^2 & 4.5 \le M_z < 6.0 \\ 0.9431 - 0.2041M_z + 0.0117M_z^2 & 6.0 \le M_z < 9.5 \\ 0.0601 & M_z \ge 9.5 \end{cases}$$

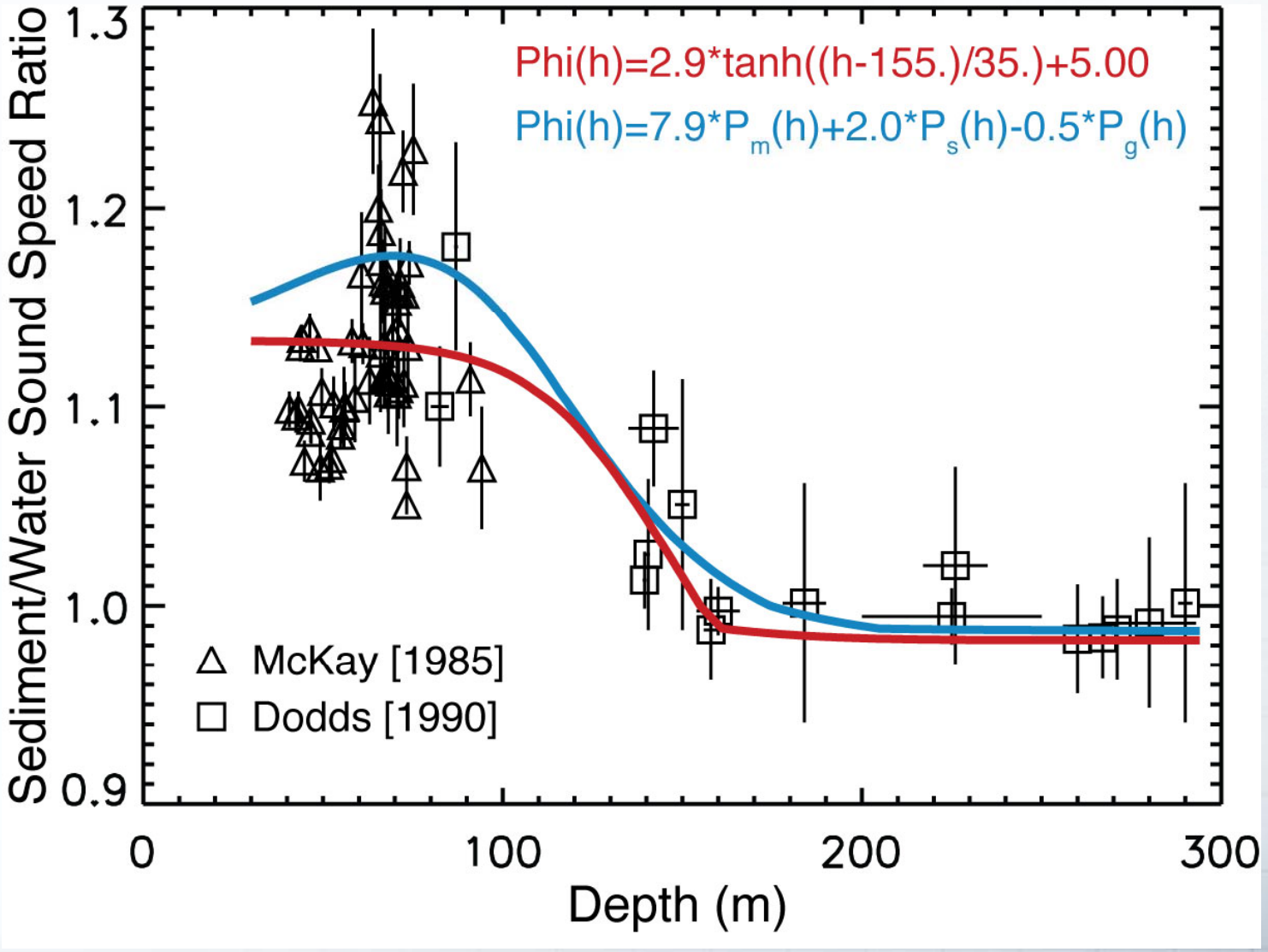
Grain Size and Sound Speed Ratio



Historical Sound Speed Data in Study Area

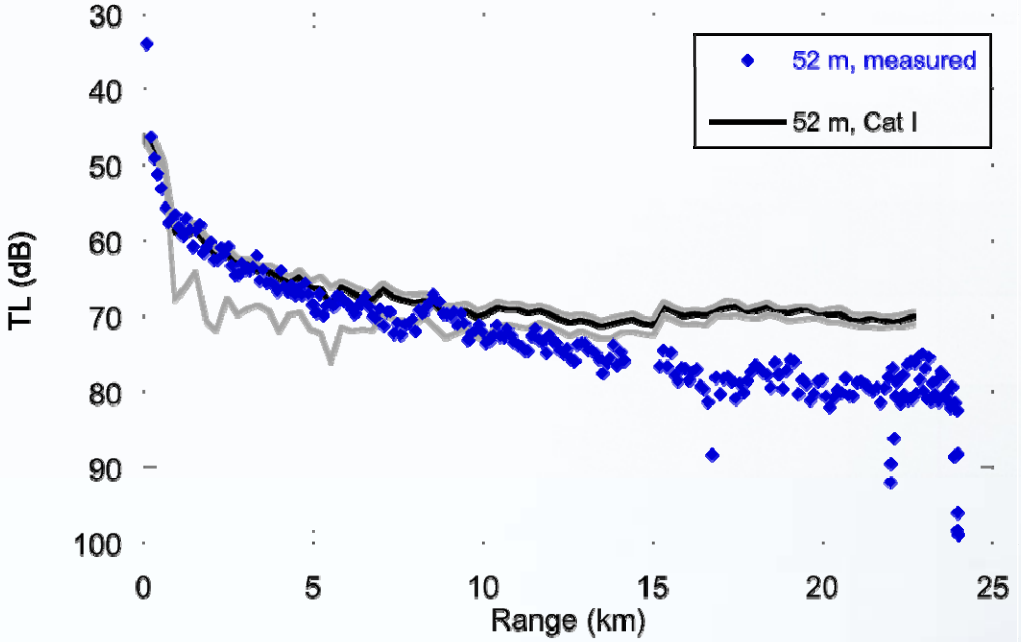


Sound Speed Calculated using the Grain Size Formulae

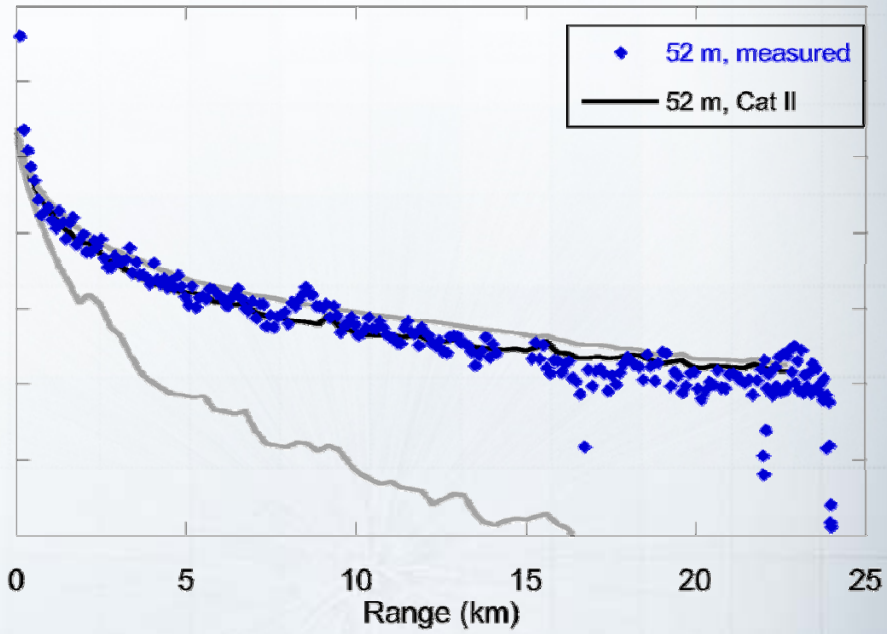


Transmission Loss: Model & Data Comparison

Initial Seabed Parameters



Revised Seabed Parameters

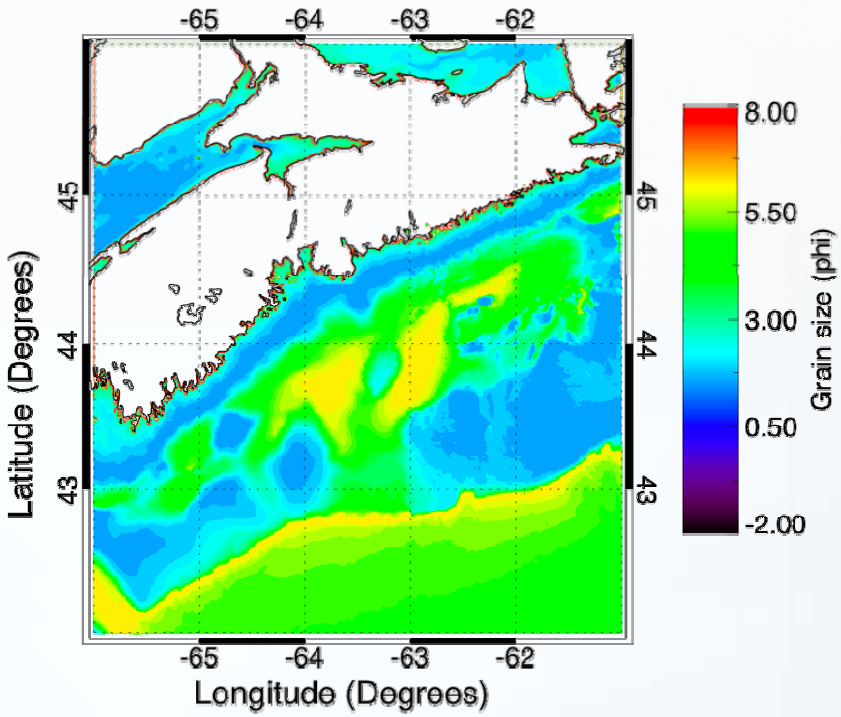


- TL estimate significantly improved using approximate formula for geoacoustic properties based on water depth.
- *Large uncertainty envelope (gray lines) because seabed is range-dependent but treated as range-independent in this modelling.*

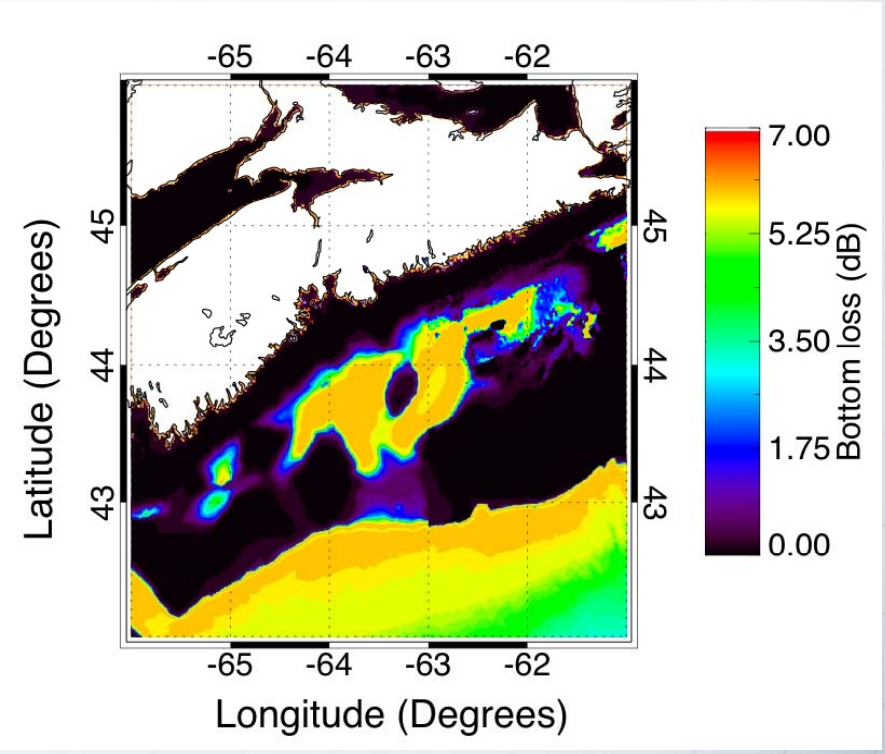
c_p =1645±166 m/s, ρ = 1.64±0.44, α = 0.600±0.365 dB/m-kHz

From Bathymetry to Bottom Loss: example is 3 degrees at 1000 Hz

Bathymetry to Grain Size

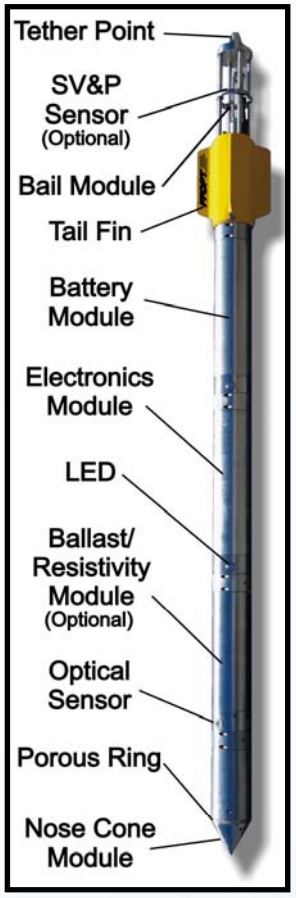


Grain Size to Bottom Loss

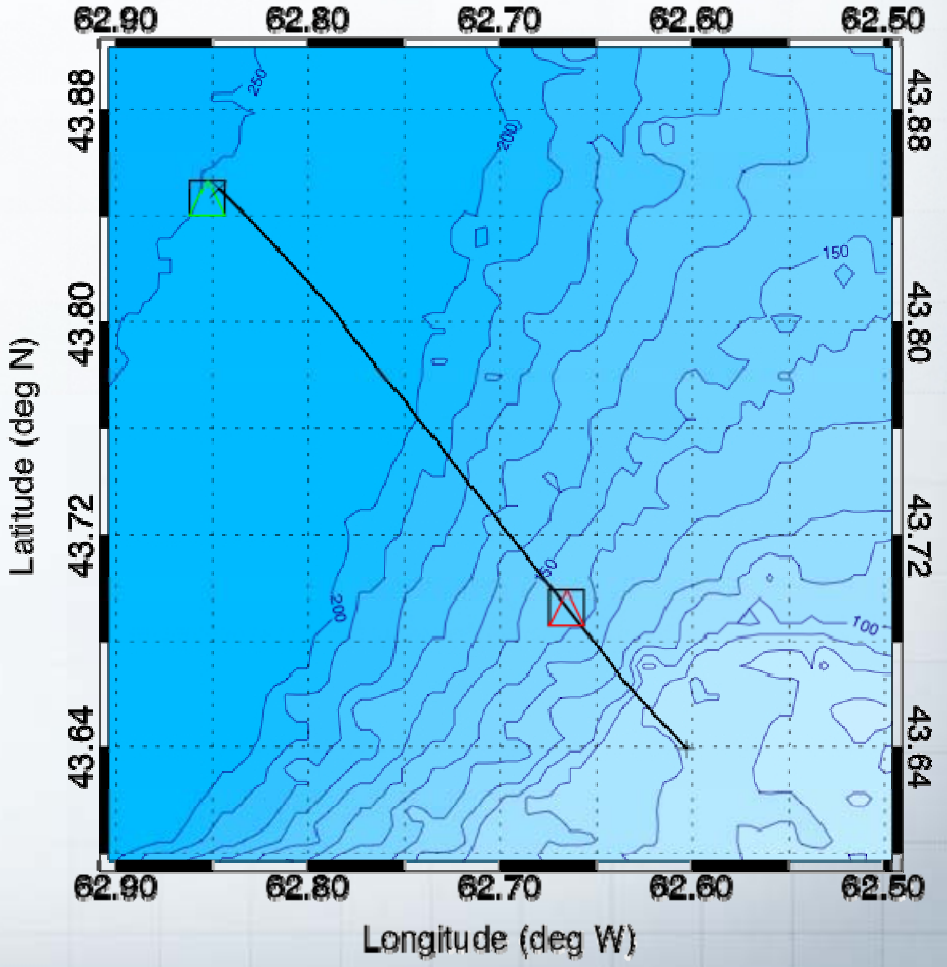


Work in Progress – Comparison with Penetrometer

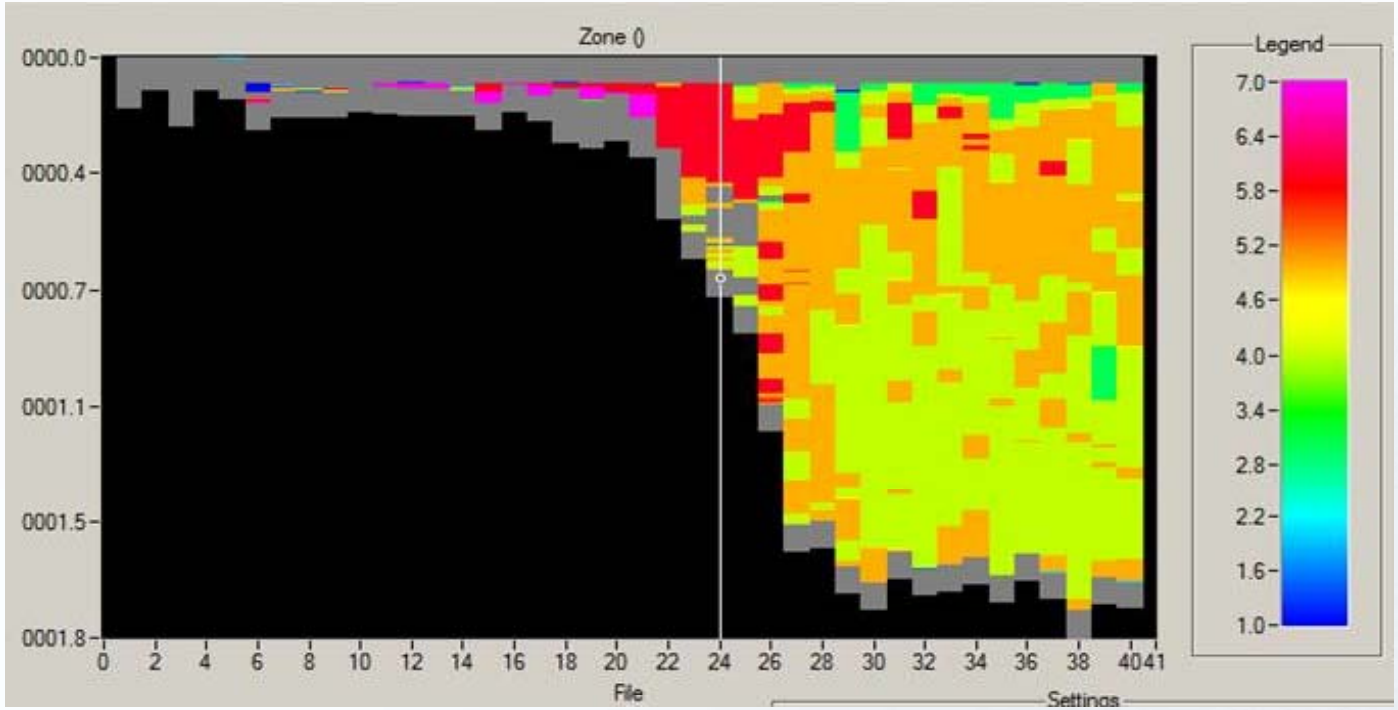
Freefall Cone Penetrometer Test
Cat. IV REA tool



FFCPT drops every ~1 km while vessel towing acoustic source



Work in Progress – Comparison with Penetrometer



Depth Below Seabed (m)

Drop Number (~Range in km)

Soil Behaviour
7 = gravel
6 = sand
5 = Sandy Silt
4 = Silt
3 = Mud

Acknowledgements

- DRDC Atlantic: S. Pecknold, A. Isenor, A. Webb, D. Graham
- GSC Atlantic: N. King, M. Furlong
- ODIM Brooke Ocean: S. Smyth

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