

# Comparison of 3D seismic reflection and multibeam sonar seafloor surface renders in deep water



ENCANA

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## Objective:

To present quantitative aspects of resolution and precision of 3D seismic and multibeam sonar seafloor surface renders, as they pertain to the deep water regions of the Scotian Slope.

Definitions (- SEG Encyclopedic Dictionary of Exploration Geophysics, 1999):

### Resolution (Accuracy and Precision)

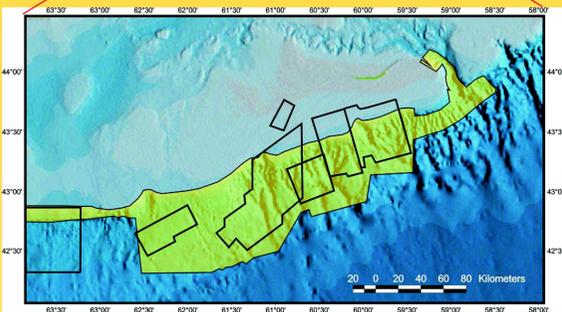
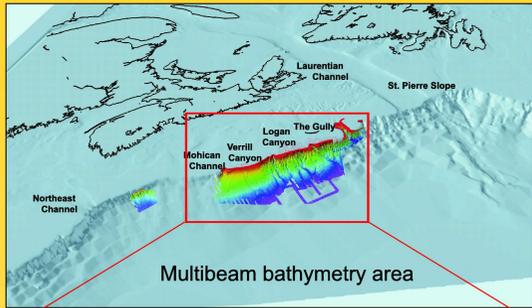
"Resolution is the ability to separate two features that are very close together; the minimum separation of two bodies before their individual identities are lost"

### Detectable Limit (Limit of Visibility)

"The minimum thickness for a bed to give a reflection that stands out above background. Sometimes taken as approximately 1/30 the dominate wavelength. (Temporal) Ability to discover and distinguish two features that are very similar (Spatial)"

### Mappable (Map Correlate)

"Place in or bring features into proper relationship with one another"



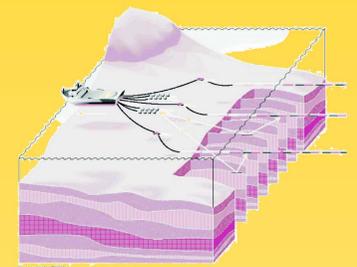
3D Seismic survey areas (black outlines)

System Specifications	
<b>Multibeam Sonar</b>	<b>3D Seismic Reflection</b>
>22,000 km <sup>2</sup> of data	>20,000 km <sup>2</sup> of data
EM300	3-100 Hz (3850-4450 in <sup>3</sup> )
30 kHz	6-8 streamers towed simultaneously
2.0 and 10.0 ms pulse lengths	6000-8000 m long
135 beams over 150° sector	12.5 m group spacing, 240 channels
1° width x 2°/cos(steering angle)	100 m between streamers
Full Motion Compensation	50-75 m shot interval
0.2% of water depth accuracy	60 fold data
EM1002	bin spacing 12.5 - 37.5 m
98 and 93 kHz	2-4 ms sample interval (250-500 Hz)
0.7 and 2.0 ms pulse lengths	Source frequency 10-100 Hz
111 beams over 150° sector	
2° x 2° beamwidth	
roll compensation only	
0.2% of water depth accuracy	

Issues of Resolution (Accuracy and Precision)	
<b>Spatial (horizontal)</b>	<b>Temporal (vertical)</b>
- Acoustic footprint (beam pattern)	- Wavelength (frequency)
- Sounding density	- Sample interval
- Grid interval	- Phase
- Acoustic raypath	- Traveltime conversion



Multibeam sonar works by generating an array of acoustic beams which spread out from the transducer in a fan-shaped pattern. This fan is wide side-to-side and narrow in the fore-aft direction. Sounding density is governed by the separation between beams and the pulse interval. In deep water, a greater time is necessary between each pulse emission to allow the sound to travel down to the seafloor and return.



3D seismic works by generating a relatively omnidirectional sound source which is received by an array of hydrophone streamers. These streamers are typically 6-9 km long. Sounding density is controlled by the number of streamers and the streamer separation, the number of hydrophones in each streamer and the shot interval.

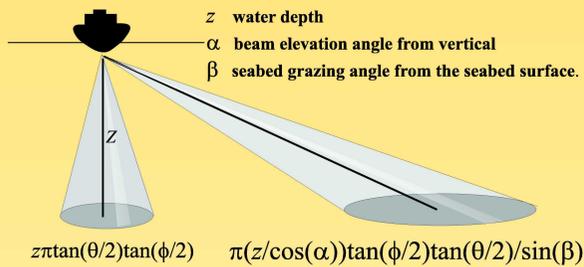
Ultimately, resolution capability is governed by two critical parameters:

**Area of Ensonification,**  
and  
**Sounding Density**

## Multibeam

### Beam Pattern

- $\phi$  beam width along track orientation
- $\theta$  beam width in the cross track orientation
- $z$  water depth
- $\alpha$  beam elevation angle from vertical
- $\beta$  seabed grazing angle from the seabed surface.



The principal of multibeam sonar is that a suite of narrow beams are generated that sweep through a range of angles relative to the vertical. The beams are generated either through mechanical or beamforming techniques. The "footprint" or area of ensonification of each of these beams expands in a radial pattern away from the transmitter due to spherical divergence. As the vertical incident beam has the shortest travel path to the seafloor, it undergoes the least divergence and, therefore, has the smallest realizable footprint. The outermost beams have the longest travel path and ensonify the seafloor at a shallow grazing angle. They have, therefore, the largest acoustic footprint.

## Area of Ensonification

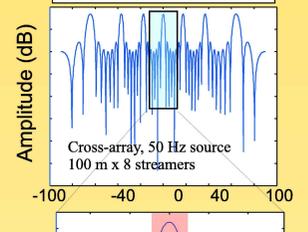
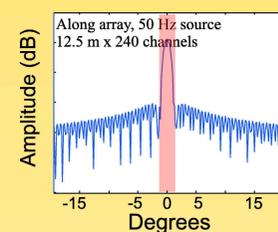
Water depth (m)	Area of Ensonification (m <sup>2</sup> ) (normal incidence)	Area of Ensonification (m <sup>2</sup> ) (45° beam)	Area of Ensonification (m <sup>2</sup> ) (75° outer beam)	Area of Ensonification (m <sup>2</sup> ) For Seismic data 2°x4° beam (normal incidence)
200	19	43	1,104	76
400	77	213	4,424	306
800	308	871	17,697	1,225
1500	1,077	3,041	62,340	4,308
2000	1,914	5,421	110,363	7,660

Theoretical area of ensonification in m<sup>2</sup> for multibeam and 3D seismic data.

## 3D Seismic

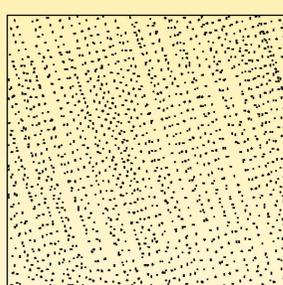
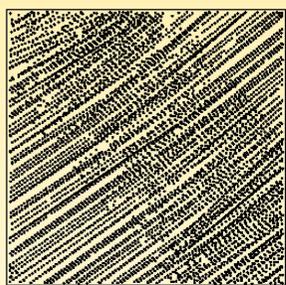
### Beam Pattern

$$A(\sigma) = A_0 \sum_{n=1}^m e^{i \frac{n \sigma L_f}{v \cos \sigma}}$$



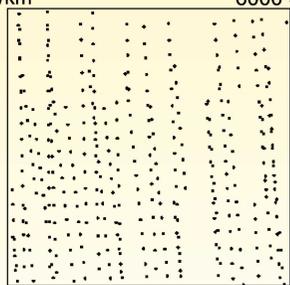
In seismic reflection data, the long hydrophone streamers act as long receiving antennae. Combined with post-processing corrections (e.g normal moveout and 3D migration), they have strong beamforming capabilities, as shown in the models above. Despite the omnidirectional and low frequency characteristics of the sound source, the long receivers focus the received signal to a about four degrees from the vertical. Beamforming in the across-array direction is less effective because of the fewer samples (6-8 streamers) and shorter separation from source to receive point. Beamforming is still focused to a few degrees but there is more ambiguity as to actual direction of the beam.

## Multibeam



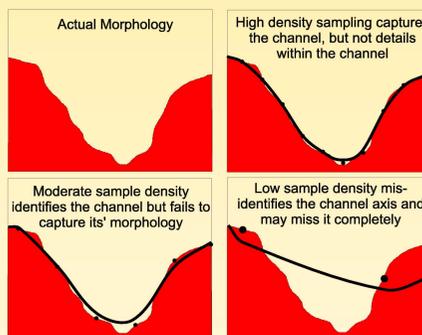
EM 1002: 180-200 m water depth  
27000 soundings/km<sup>2</sup>

EM 300: 1000 m water depth  
6000 soundings/km<sup>2</sup>

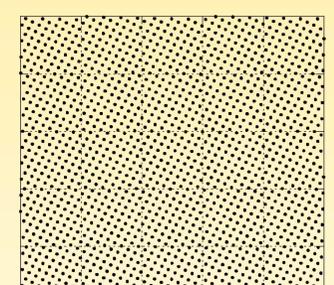
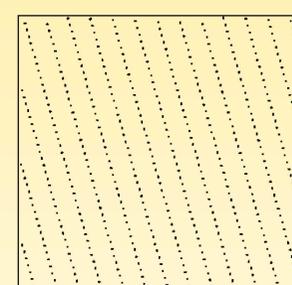


EM 300: 2100-2140 m water depth  
1500 soundings/km<sup>2</sup>

## Sounding Density



## 3D Seismic



3D Seismic 12.5 x 37.5 m grid  
2100 soundings/km<sup>2</sup>

3D Seismic 12.5 x 12.5 m bin spacing - 6400 soundings/km<sup>2</sup>

Ultimately, the ability to resolve features on the seafloor is governed by the sample density, which must obey Nyquist sampling criteria. Fewer samples means less resolution. The details cannot be recovered after the fact and any attempt to do so results in aliasing (generation of false features). The schematic above demonstrates this fact. With too few samples, the channel is not well resolved and in fact could possibly even shift in position. The displays to the left (multibeam) and right (3D seismic) show actual sample densities from studies on the Scotian Slope. In shallow water, multibeam sample densities are very high with a significant amount of redundancy. During surveying, the beam spacing was held constant in order to maximize areal coverage; thus, the sample density decreases with increasing water depth. Most multibeam systems can also be operated to maintain sample density and restrict the swath width. In 3D seismic, sample density (bin spacing) remains constant irrespective of water depth and is a function of the channel spacing in the streamers and the shot interval.

Mosher, D.C., LaPierre, A., Bigg, S., and Syhlonk, G.  
2005: Comparison of 3D seismic reflection and multibeam sonar seafloor surface renders in deep water; Geological Survey of Canada, Open File 4892, 3 sheets.

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