

Deepwater Hydrocarbon Seep Detection: Tools and Techniques using Multibeam Echosounders

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GEBCO Bathymetric Science Day - October 12, 2016

What Are Seeps: How and Why do we Hunt for Them??

Naturally occurring “leaks” from the subsurface

If we can find and sample them, we can tell

If there is the “right” geochemical signature

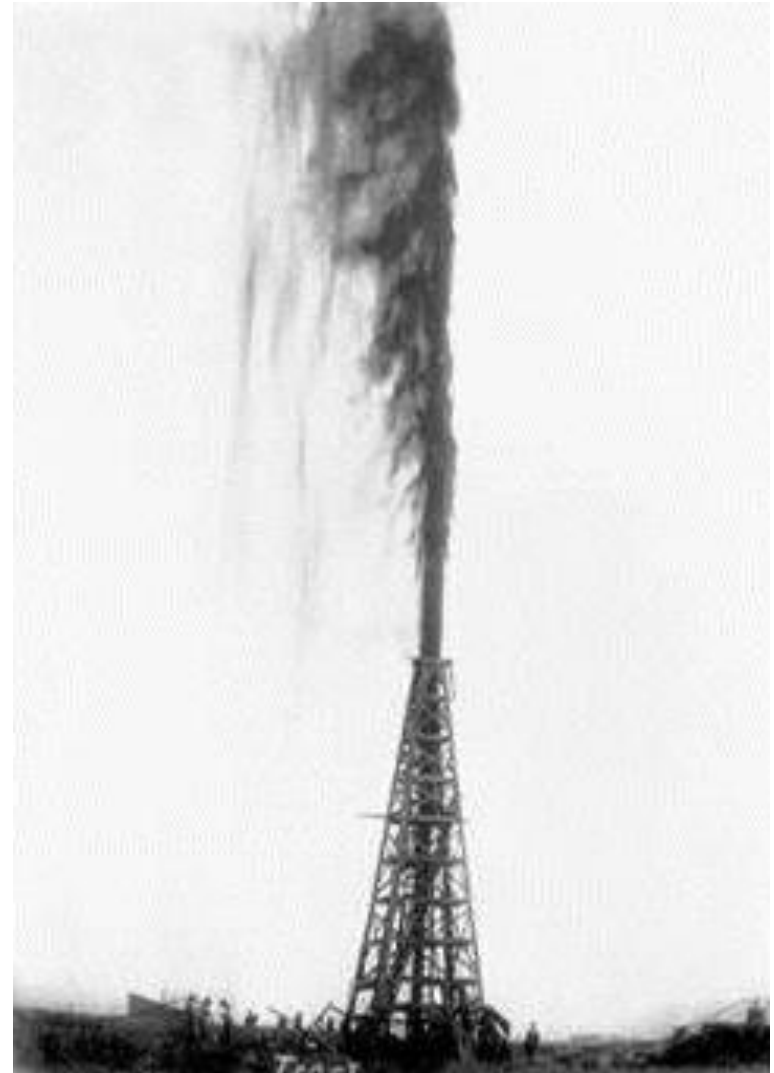
Find the “right” areas to acquire more expensive data

Seeps are difficult to find on the seafloor – so we must hunt for them!

Fugro actions

- Map with the right tool
- Skilled geologists interpret
- Sample accurately – experience counts
- Analyze the results

Clients are always kept in the loop and welcomed to contribute to all stages of the process



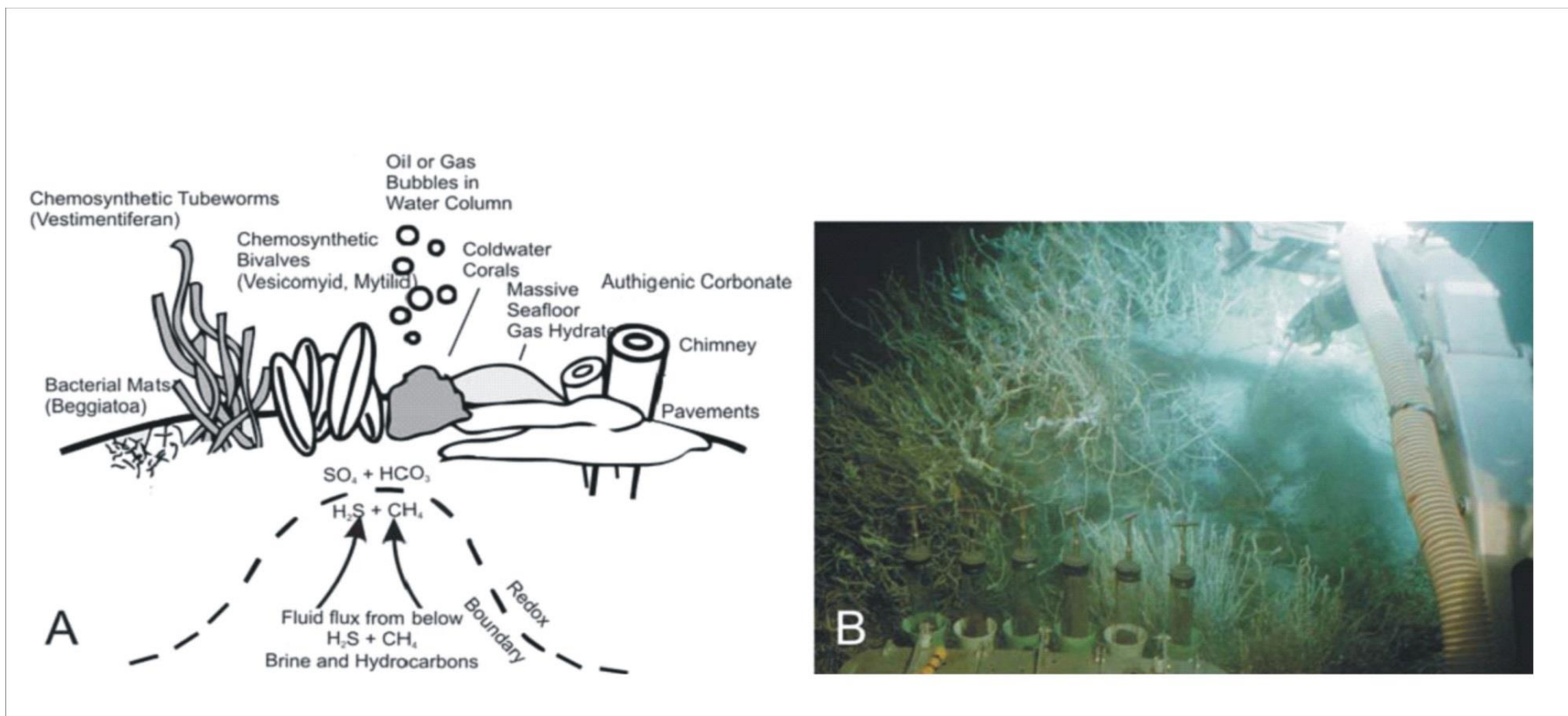
Lucas Gusher on Spindletop Hill

Seep Communities Make Great Acoustic Echoes!

Hydrocarbon seeps occur anywhere oil or gas reach the seafloor. Seeps feed chemosynthetic communities with hard shells, they form minerals, and create gas hydrate deposits.

This leads to hard – and acoustically reflective seafloor – on an otherwise soft seabed

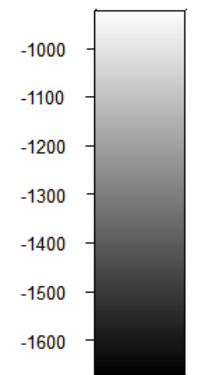
Fugro uses this to find seep locations!



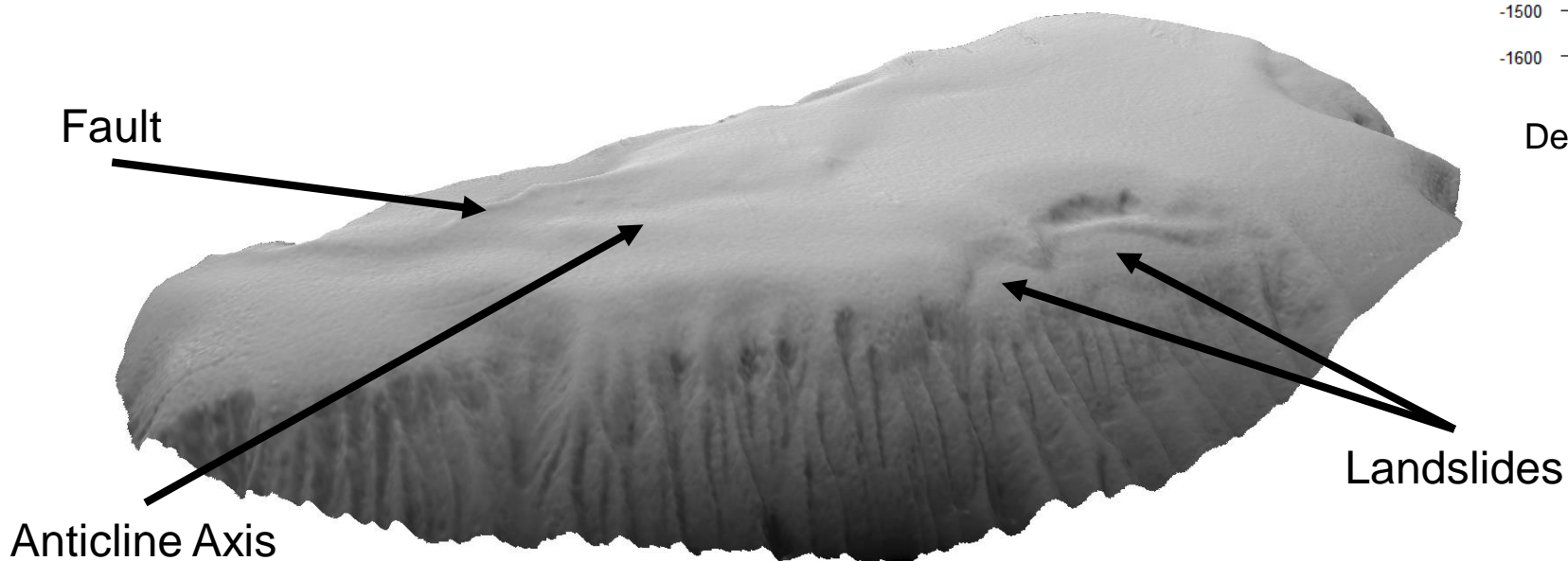
What Information is Obtained from Multibeam Data?

Bathymetry

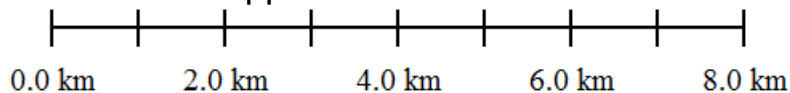
- Water depths and topography of the seafloor
- Identify geological features



Depth (m)



Approximate Scale



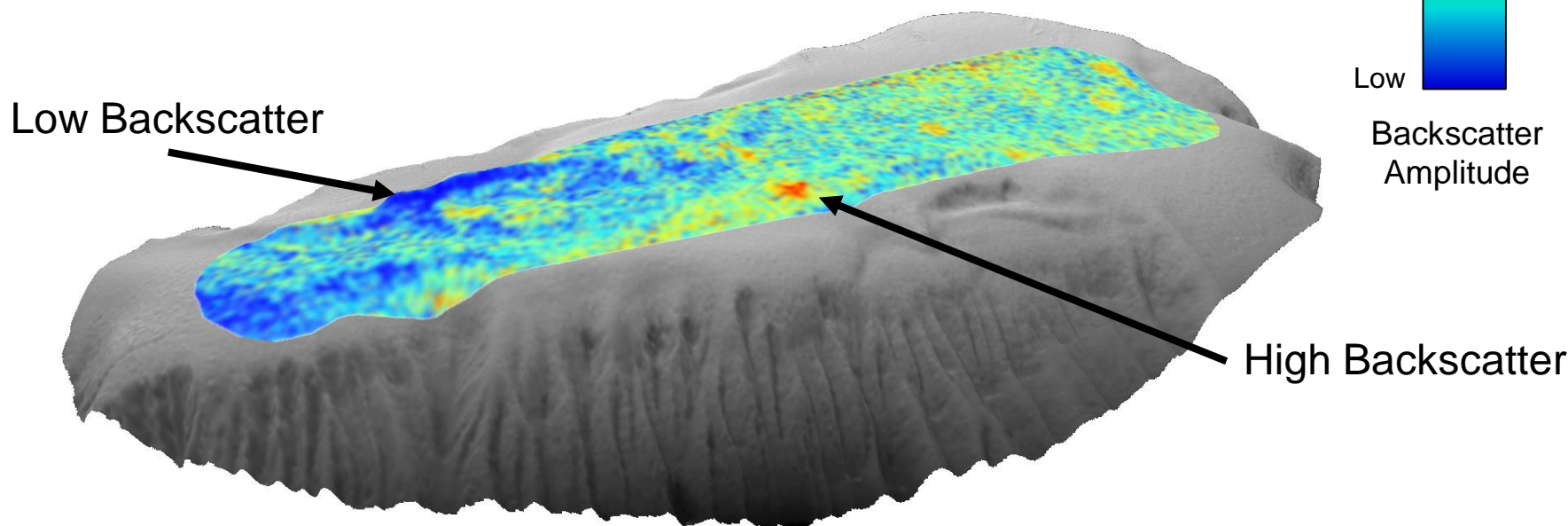
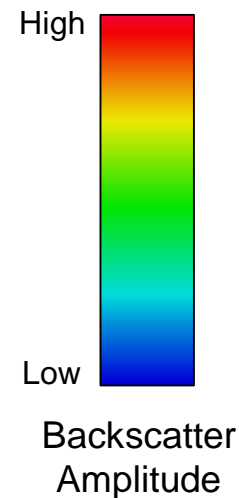
Data courtesy of Anadarko New Zealand Company
Collected by Fugro GeoConsulting, Inc. and NIWA

Bathymetry Vertical Exaggeration = 3x

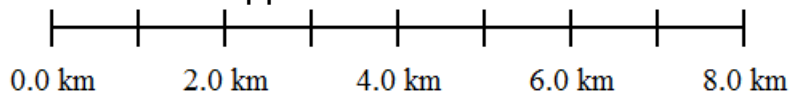
What Information is Obtained from Multibeam Data?

Backscatter Intensity

- Amount of acoustic energy of the seafloor
- Higher backscatter = harder substrate
- Lower backscatter = softer substrate



Approximate Scale

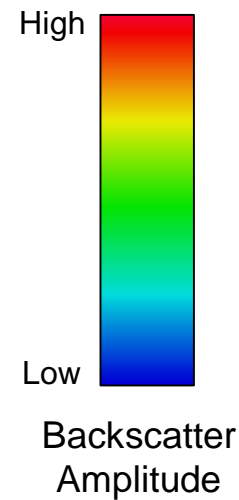
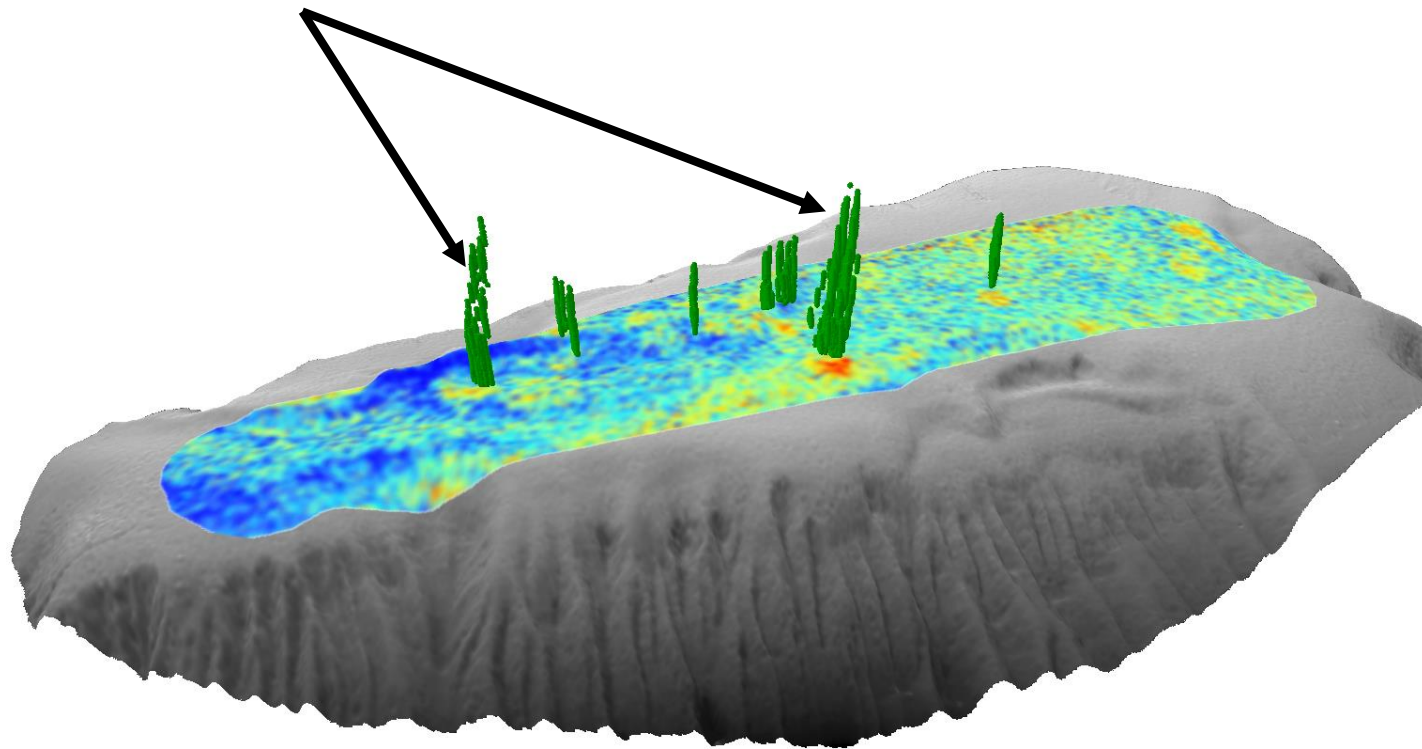


Data courtesy of Anadarko New Zealand Company
Collected by Fugro GeoConsulting, Inc. and NIWA

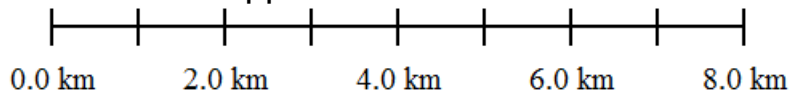
Bathymetry Vertical Exaggeration = 3x

What Information is Obtained from Multibeam Data?

Water Column
Anomalies



Approximate Scale



Data courtesy of Anadarko New Zealand Company
Collected by Fugro GeoConsulting, Inc. and NIWA

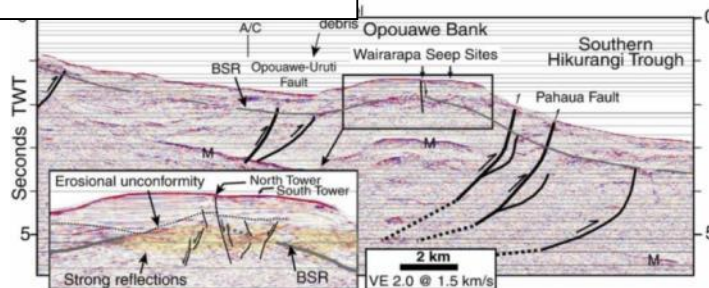
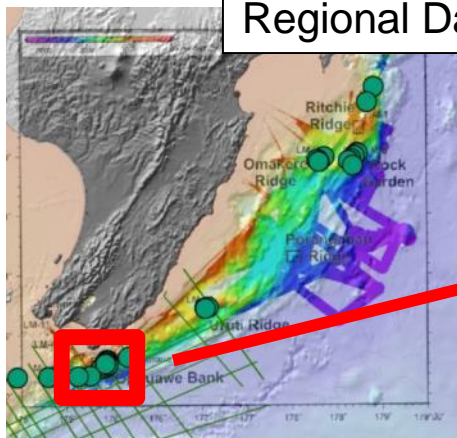
Bathymetry Vertical Exaggeration = 3x



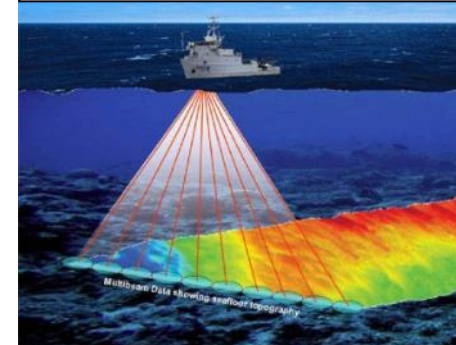
An Integrated Exploration Process

Target Identification

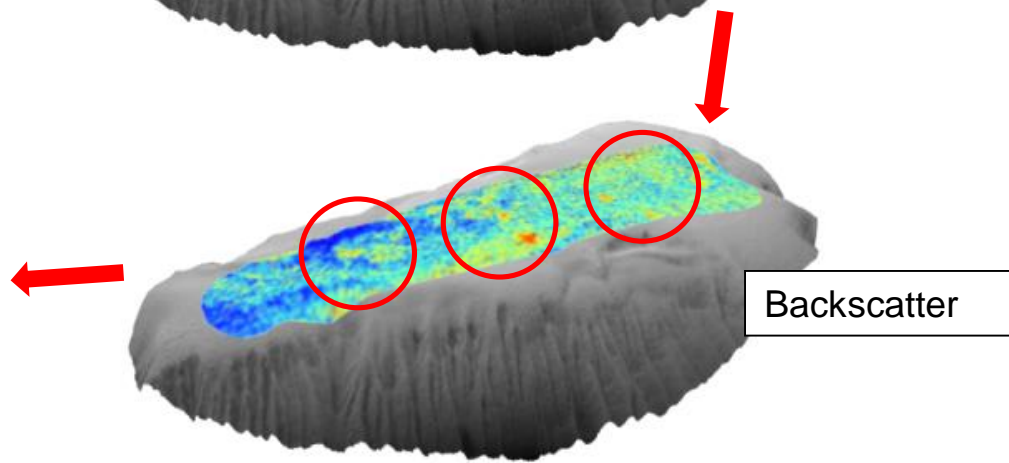
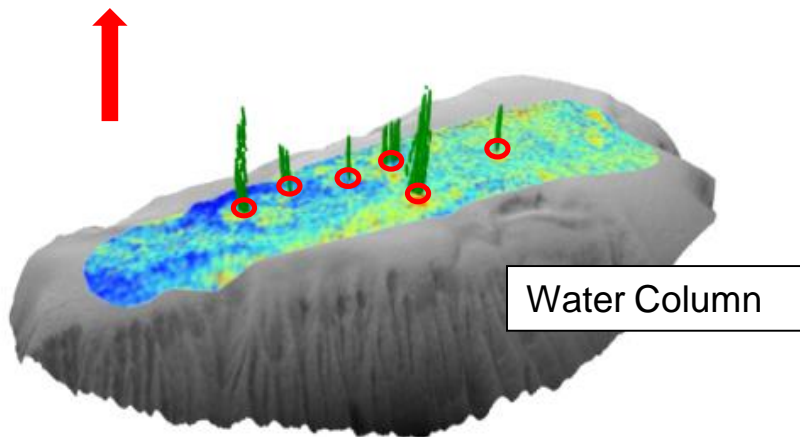
Regional Data and Assessment



New Multibeam Data



All interpretative stages need geologic expertise and experience to optimize the geochemical sampling location.

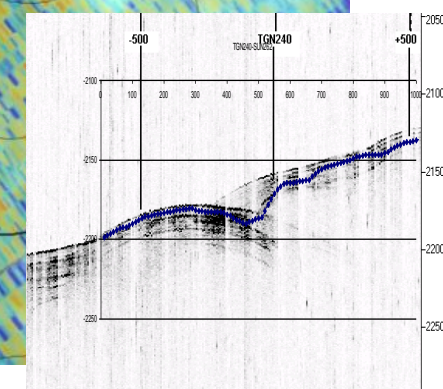
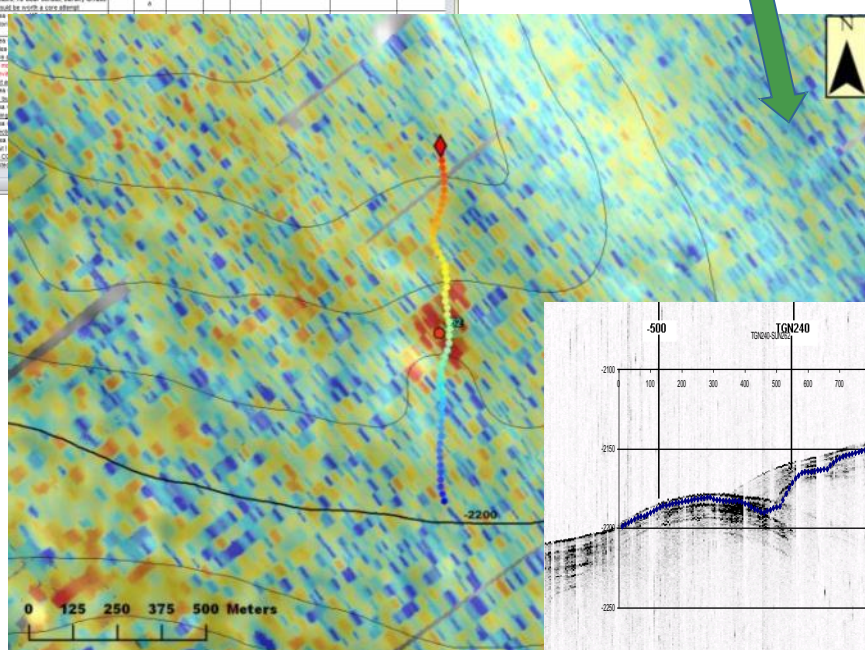
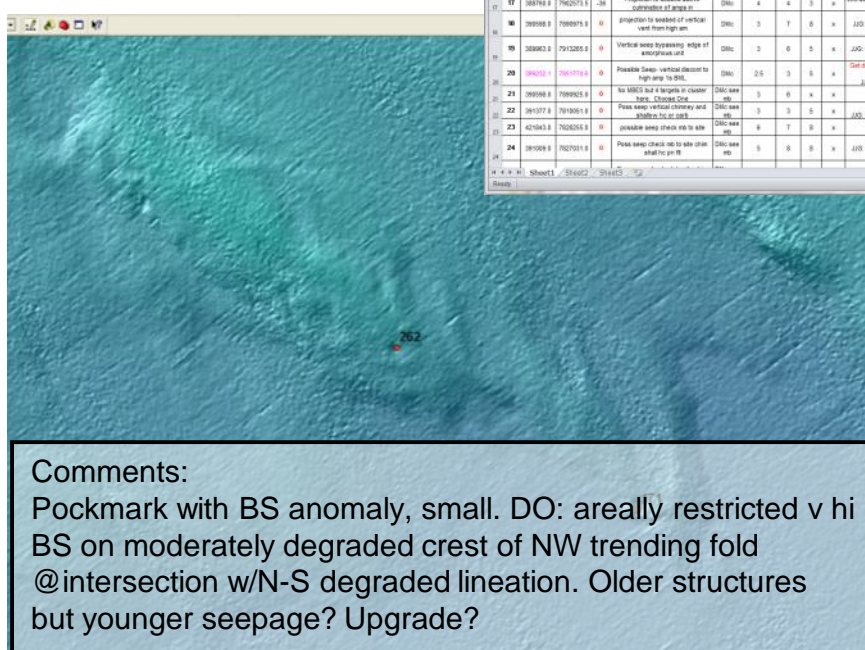


The Approach - Target Ranking and Optimization

Targets are Identified and Graded/Ranked

ID	X	Y	Z	COMMENTS	COORDINATE	NAME	JIG	JIG	JIG	JIG	JIG	Secondary Comment (SPP rank of "Y" - "Zending")	SPP	REMARK	REMARK	REMARK	REMARK	
2	281151.0	705400.0	-1420	BS discontinuity. Small of canyon... faulted to horizontal...	DOIC	3	4	6	6	6	JIG bright spot in reflectivity. washed out reflects. what about SP discontinuity roughly. Turn to CSE?? That looks promising.	0	1	1				
3	246382.0	705596.0	-1440	small top of high amp of anomaly...	DOIC	3	9	9	8	6	JIG small surface bright spot. not much other indication.	0						
4	468327.0	706206.0	5	pass tempo. chimney in well. Center from original...	DOIC	3	3	3	3	6	JIG small banding with some bright reflects. downhole DOIC moved to its anomaly in flat area. need to re-curve.	1	1	1				
5	401748.4	706003.7	-27	shallow fault intersects top of canyon...	DOIC	2	5	4	4	6	JIG possible fault. buried north-south. near edge of the DOIC revealed to fault means.	1	1	1				
6	287910.0	706912.4	-27	small fault intersecting high amp...	DOIC	5	7	8	6	6		0						
7	288317.0	701403.0	-240	graben if a fault to target...	DOIC	4	2	6	6	6	JIG under fault. likely contact.	0		108	110			
8	446221.0	702208.0	6	at fault intersects top of canyon...	DOIC	2	3	4	4	6	DOIC Revealed to be high local...	1	1	1				
9	282226.0	707847.0	-240	intra canyon zone west area...	DOIC	7	7	8	6	6	JIG Good graben or dipping reflectivity. near at JIG. the fault is probably processing artifact. Bright spots probably not a target. caused by increase down reflectivity. but unlikely to have any kind of edge of target.	0						
10	283468.0	705000.0	400	possible horizon. below the...	DOIC	5	4	6.5	6	6	JIG Very strong member. could be a target?	1	1	1				
11	279144.0	701403.0	-600	High BS in SW. Canyon below...	DOIC	3	4	4	4	6	JIG. seems on target? another feature. high amplitude reflectivity. JIG. seems on target? another feature. high amplitude reflectivity.	1	1	1	11	20.50		
12	282473.0	701403.0	-600	Soft spot? High gas area below...	DOIC	4	6	3	6	6	JIG. seems on target? another feature. high amplitude reflectivity.	1	1	1	12.34			
13	237079.0	704820.0	-800	High BS. window gas within...	DOIC	5	6	4	6	6	JIG. window into deeper reflects. might be fault. As then good target. if not then look for...	0						
14	288808.0	705107.0	-240	move to 288807.0 705122.0...	DOIC	3	7	4	6	6	JIG. off-patch target. near dipping fault. hard to core location. DOIC. reveal that feature. look to be good prospective.	1	1	1				
15	273768.0	706270.0	400	low BS anomaly. artifact or soft...	DOIC	3	3	6	6	6	JIG. channel seems sub-parallel to line of patches? or seed bodies warning into channel? Clones might be fault negative correlation.	1	1	1				
16	288904.0	704961.0	0	east of fault but from that...	DOIC	3	3	6	6	6	JIG. don't know if this is an artifact (S) or not (S).	0						
17	288780.0	706207.0	-38	Proposed to be...	DOIC	4	4	3	6	6	JIG. still needs to check consistency. or other context. but very diffuse.	0						
18	288980.0	708007.0	0	projection to location of vertical...	DOIC	3	7	8	6	6	JIG. bright reflects but not...	0						
19	288963.0	701205.0	0	Vertical zone...	DOIC	5	6	5	6	6	JIG. revealed out amplitude...	0						
20	289250.0	701770.0	0	possible...	DOIC	2.5	3	5	6	6	JIG. Get depth from...	0						
21	289798.0	709900.0	0	No BS...	DOIC	3	8	6	6	6	JIG. seems on target...	0						
22	289107.0	701800.0	0	Pass...	DOIC	3	3	6	6	6	JIG. No...	0						
23	427043.0	704820.0	0	possible...	DOIC	6	7	3	6	6	JIG. bright...	0						
24	281009.0	702703.0	0	Pass...	DOIC	5	8	6	6	6	JIG. Not...	0						

Optimizing still continues throughout the coring operation (including reshooting targets)



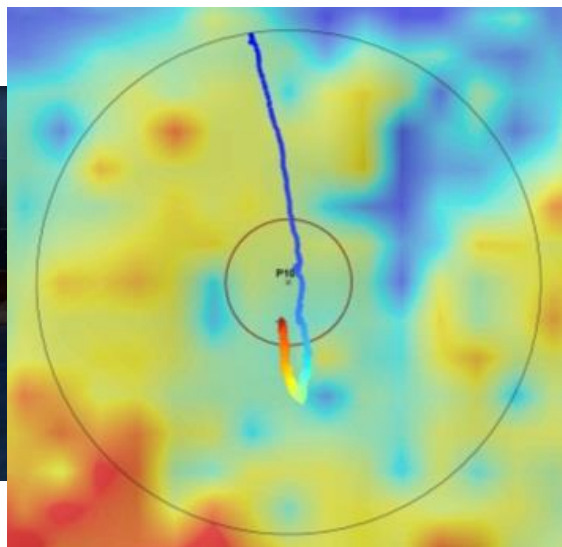
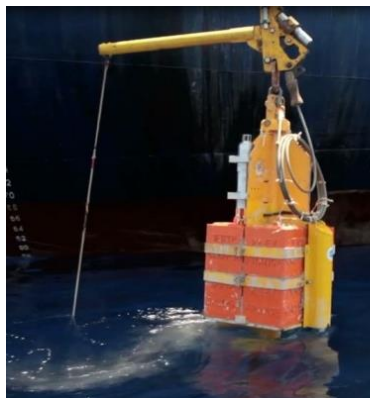
Comments:
 Pockmark with BS anomaly, small. DO: areally restricted v hi BS on moderately degraded crest of NW trending fold @ intersection w/N-S degraded lineation. Older structures but younger seepage? Upgrade?



Precision Seep Sampling

Understanding the Target

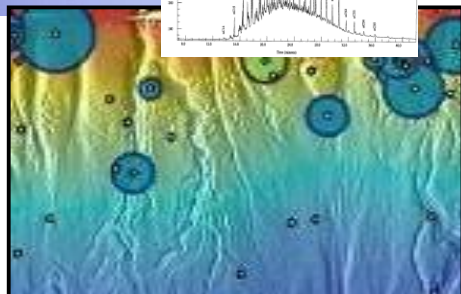
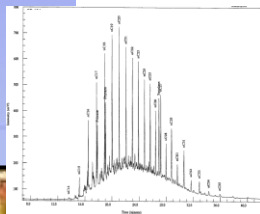
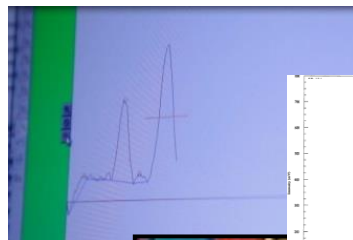
Making sure the core hits the target



All interpretative stages need geologic expertise and experience to optimize the geochemical sampling location.



Core recovery with seep-related hardgrounds at the base

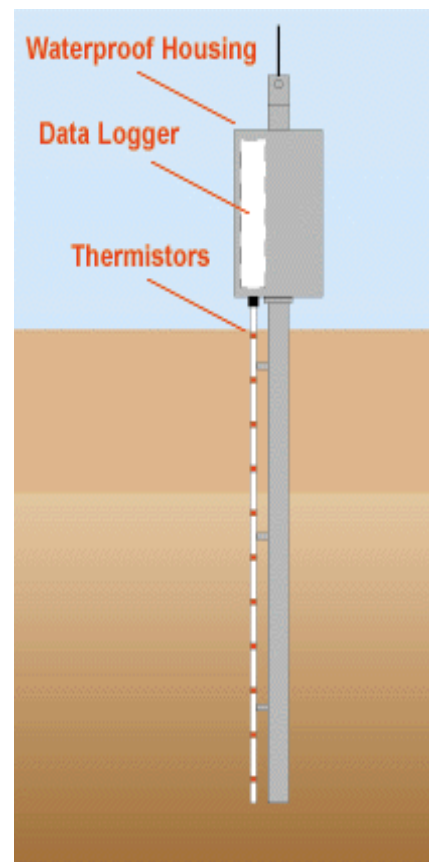
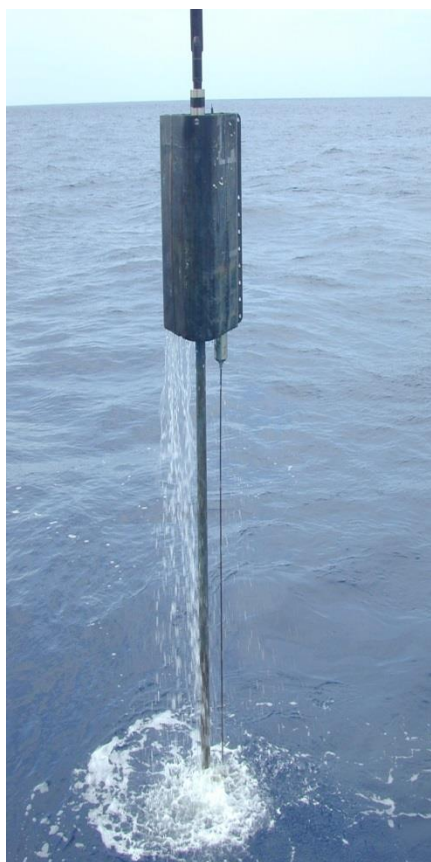


*Headspace gases C1-C5 can be analyzed **on the vessel** to confirm targets, while sediment extracts can be sent to shore-based laboratory more comprehensive analysis*



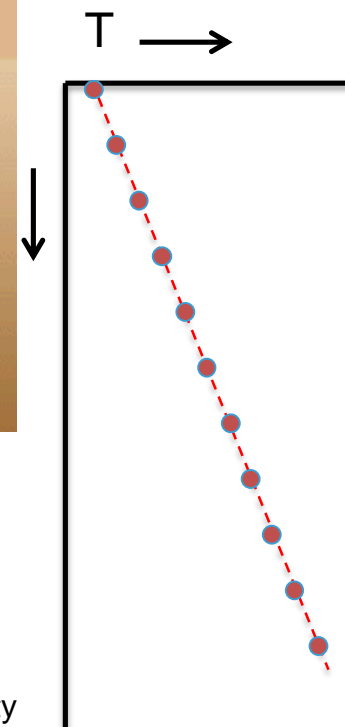
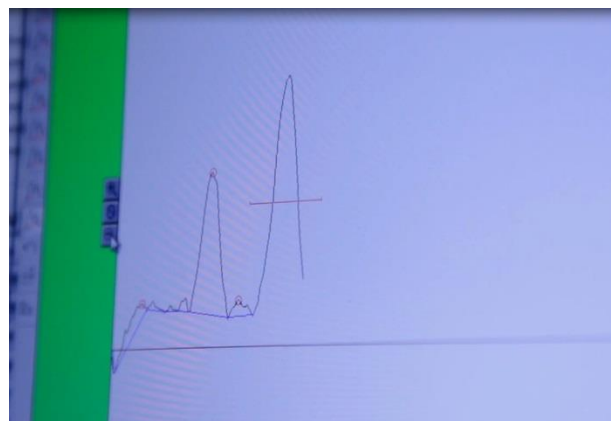
Gas-parting and fine-grained gas hydrates in the sediment

Optional Onboard Analysis – Geochemistry and Heatflow



$$Q = -K \frac{dT}{dZ}$$

dT/dZ & K
measured
in situ



Head space gases C1-C5 can be analyzed on the vessel to confirm targets while sediment extracts can be sent to shore-based laboratory for gasoline range and heavy hydrocarbon (C15+) analysis

Exclusive partnership with US National Academic Heat Flow Facility at Oregon State University

Seep-Hunting & Geochemical Campaigns Benefits

Frontier Region Exploration is Risky & Costly

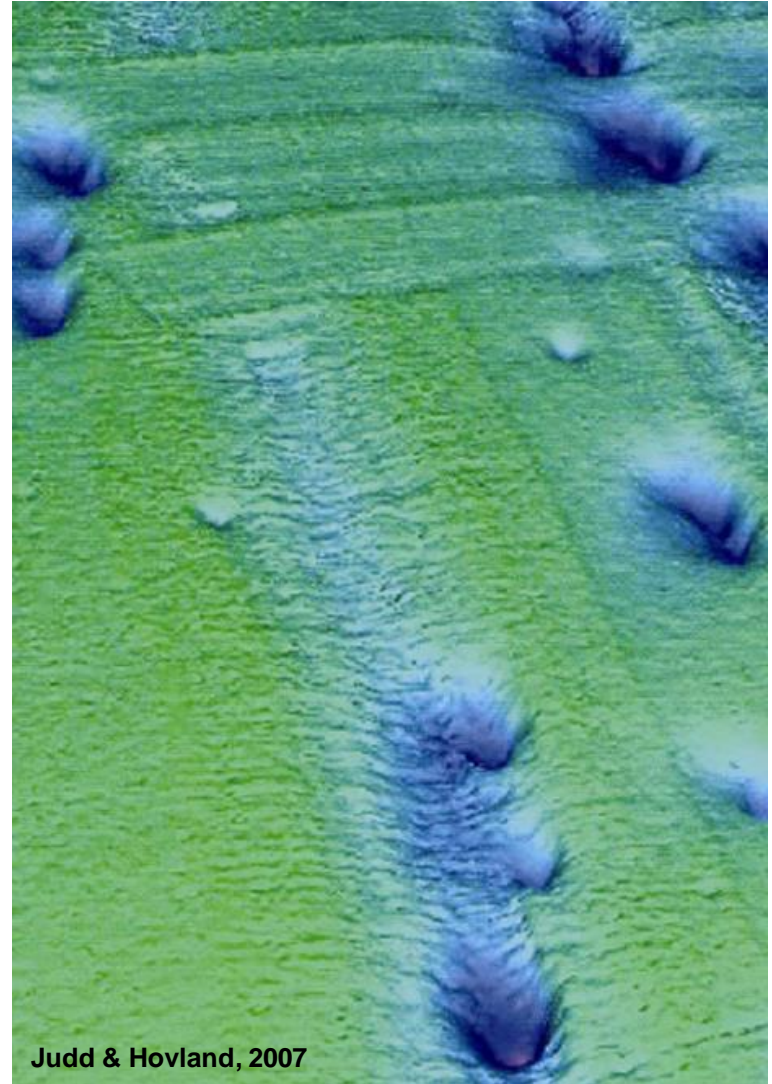
Seep Campaigns Can Reduce Risk & Cost

Yield insights to the system

- Seafloor and shallow subseafloor geologic features
- Geochemical composition of the reservoir
- Maturity of hydrocarbon system
- Basin evolution

Maximize return on investment & aid decision making

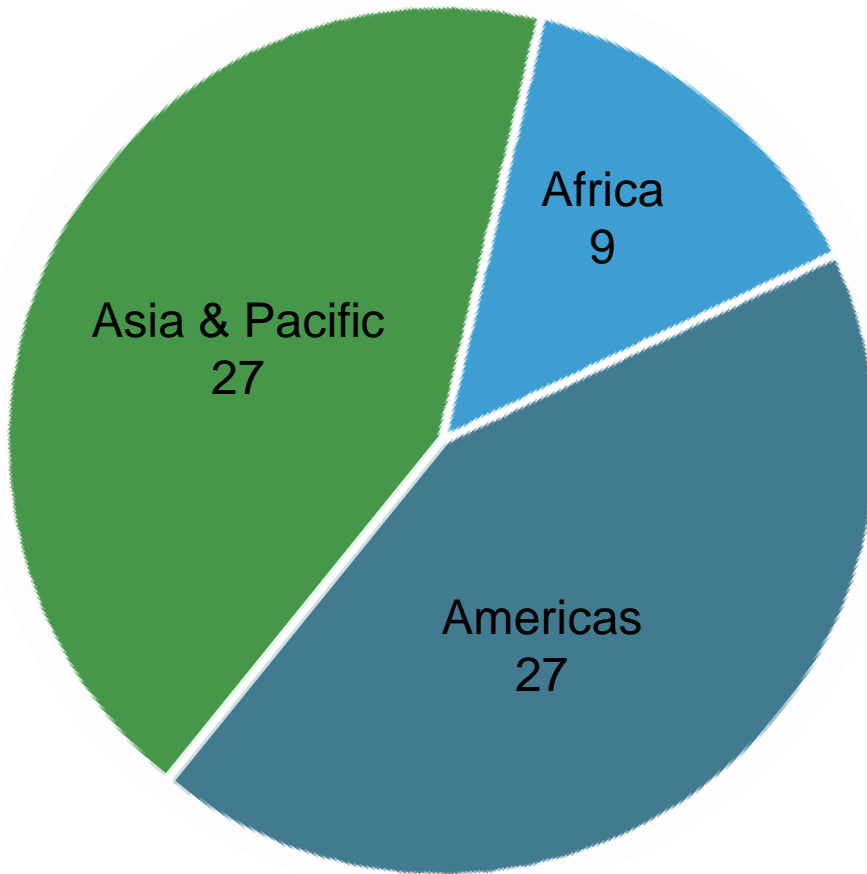
- Onboard experts can optimize ship time by making decisions based on the acquired data
- Provide guidance for prioritizing future exploration work
- Quickly map most or all of a lease block
- Seep campaign results will show you where to carry out more expensive exploration work
- Convincing evidence can be used to attract a farm-in partner
- Lack of convincing evidence for a viable hydrocarbon source means resources can be spent elsewhere



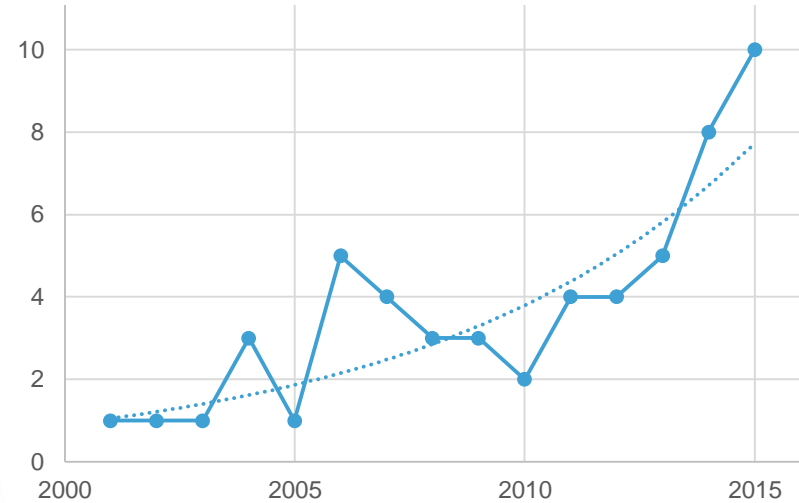
Judd & Hovland, 2007

Modern Seep-Hunting Campaigns – Gaining Industry Acceptance

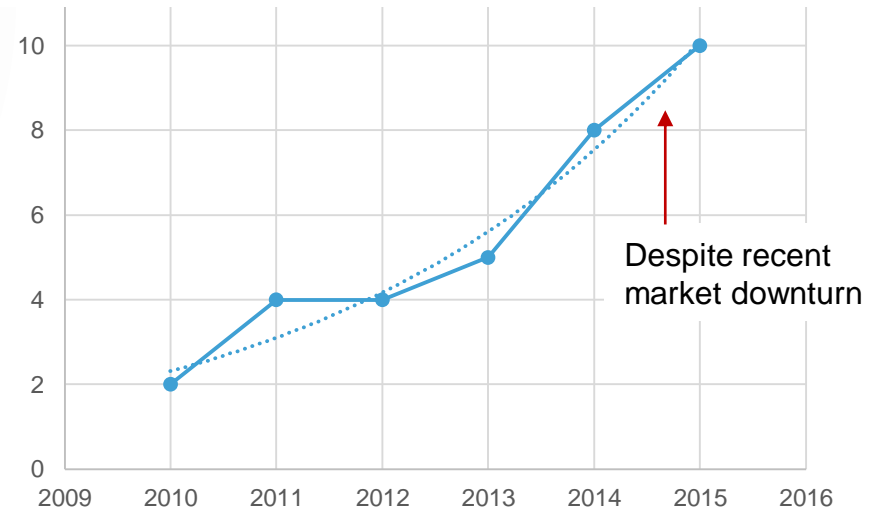
Seep Projects by Region



Projects grew annually by 14% from 2000-2015



Projects grew annually by 30% from 2010-2015



Seep-Hunting & Geochemical Campaign Experience List



BG GROUP



Fugro Seep Consultancy - Project Experience		
Region	Client	Year
Myanmar	Woodside*	2016
Myanmar	BG Group	2016
Gigante Mexico Mega Survey 1	TGS/Oro Negro Exploration*	2015-2016
New Zealand	OMV	2015
New Zealand	Chevron	2015
Vietnam	PetroVietnam	2015
Vietnam	Murphy	2015
Colombia	Shell	2015
Honduras	BG Group	2015
Australia	Statoil	2015
Aruba	Repsol	2015
Colombia	Anadarko	2014-2015
Trinidad and Tobago	BHB Billiton	2014
Kenya	Total	2014
Canada - Nova Scotia	Shell	2014
New Zealand	Statoil	2014
New Zealand	Shell	2014
Uruguay	Total	2014
Kenya	Anadarko	2014
Guyana	Anadarko	2013
New Zealand	Anadarko	2013
Mozambique	Petronas	2013
Madagascar	SA Petro	2013
Bulgaria (Black Sea)	OMV	2013
South Africa	Anadarko	2012
Brasil A-F (6 Surveys)	Niko Resources	2011-2012
Indonesia Mega Survey 2	Niko Resources	2011
Madagascar	Niko Resources	2010
Colombia	Reliance	2010
Timor	ENI	2009
South China Sea	Devon	2009
Yellow Sea	Devon	2009
Brasil	Devon	2008
Indonesia Mega Survey 1A - 1H (8 surveys)	TGS/Black Gold Exploration	2007-2008
India	Reliance	2006-2007
Brasil	Devon	2005
Turkey	BP	2004
Turkey	El Paso	2004
Northwest Africa	Kerr-McGee	2004
Indonesia	Unocal	2003
Ghana	Devon	2002
Barbados	Conoco	2001

* current project



Statoil

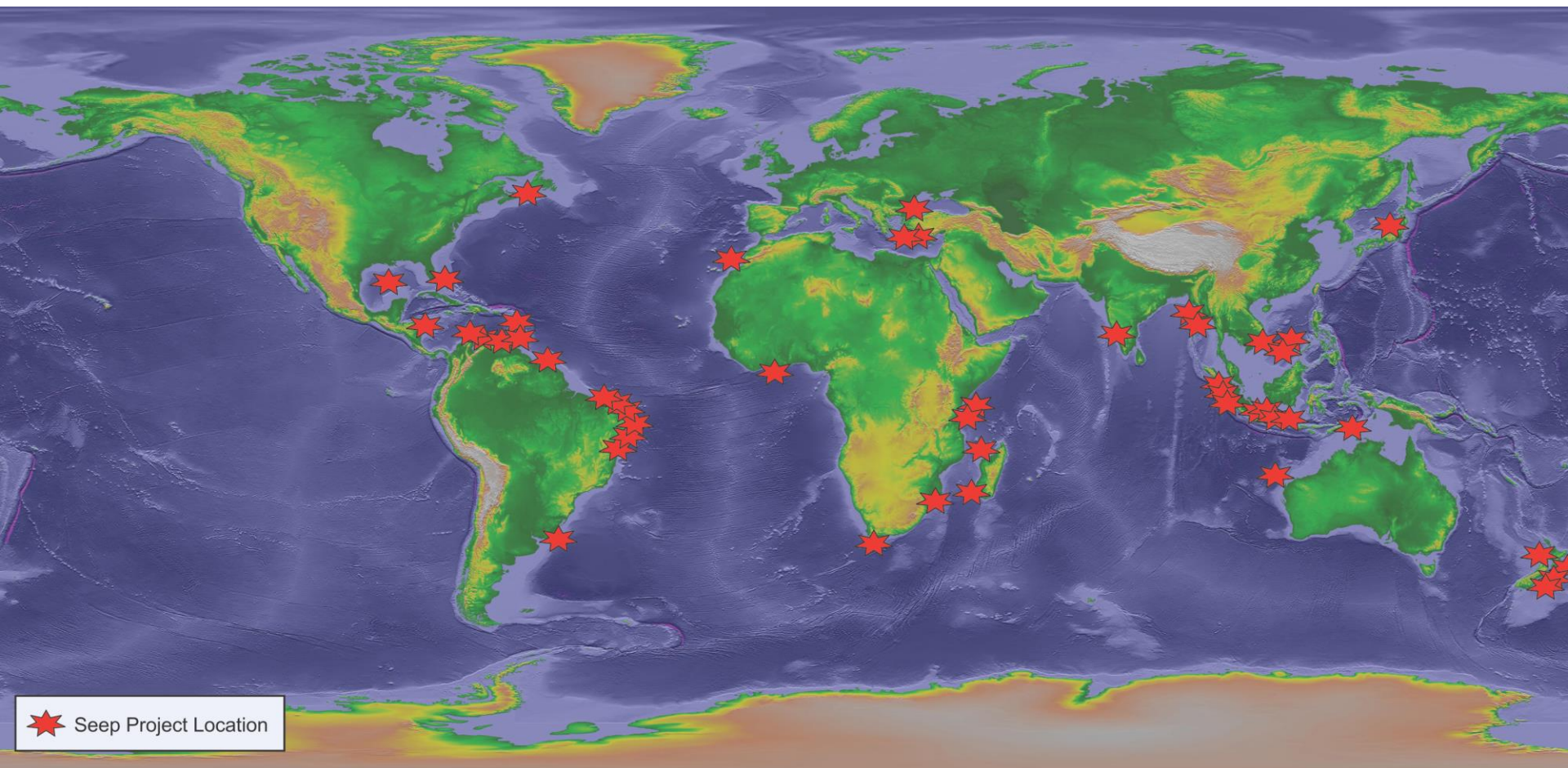


TOTAL



Fugro Seep Hunting Project Locations

- Over 50 seep hunting campaigns since 2001
- Mega-surveys in Mexico, Brazil and Indonesia
- Over 2,000,000 km² has been mapped with modern multibeam surveys
- Most data are proprietary and owned by Fugro customers ... not Fugro



Fugro Fleet for Modern Seep Hunting

- Fugro is in the midst of a strong vessel building and technology investment program
- Fugro now have 19 vessels with advanced MBES technology around the globe





Case Study : Gigante Mega Survey

World's Largest Offshore Seep-Hunting Survey

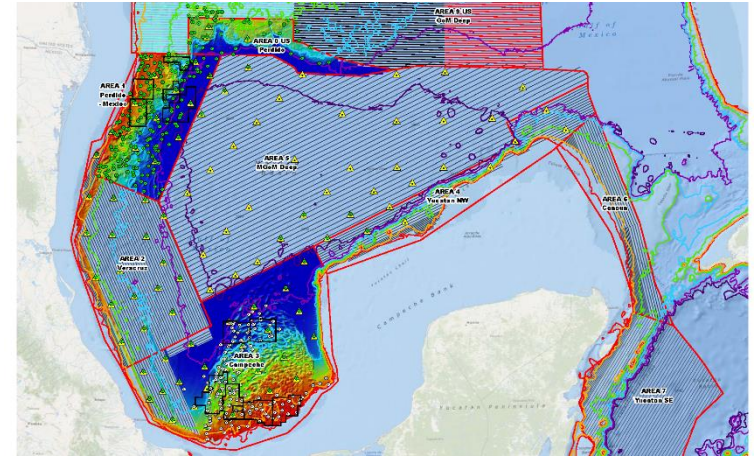
What: TGS-led, industry funded, multi-client seismic, multibeam, and coring program

When: Timed to coincide with denationalization of Mexico's O&G market

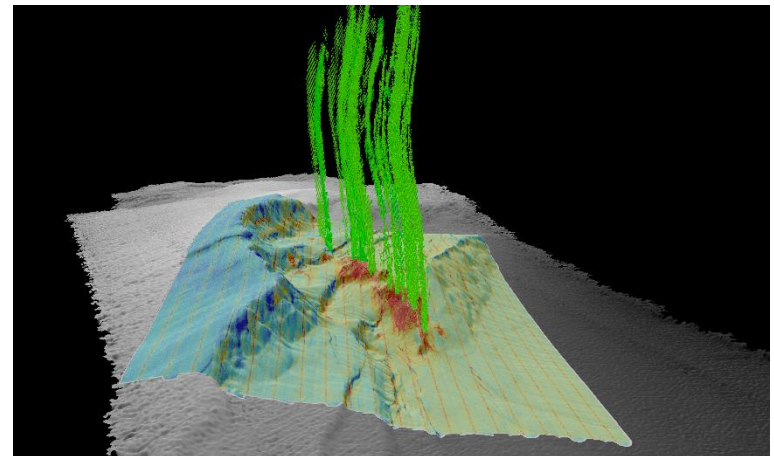
Purpose: to assist O&G clients in making investment decisions in a frontier offshore region (reduce risk)

Fugro's Scope of Work:

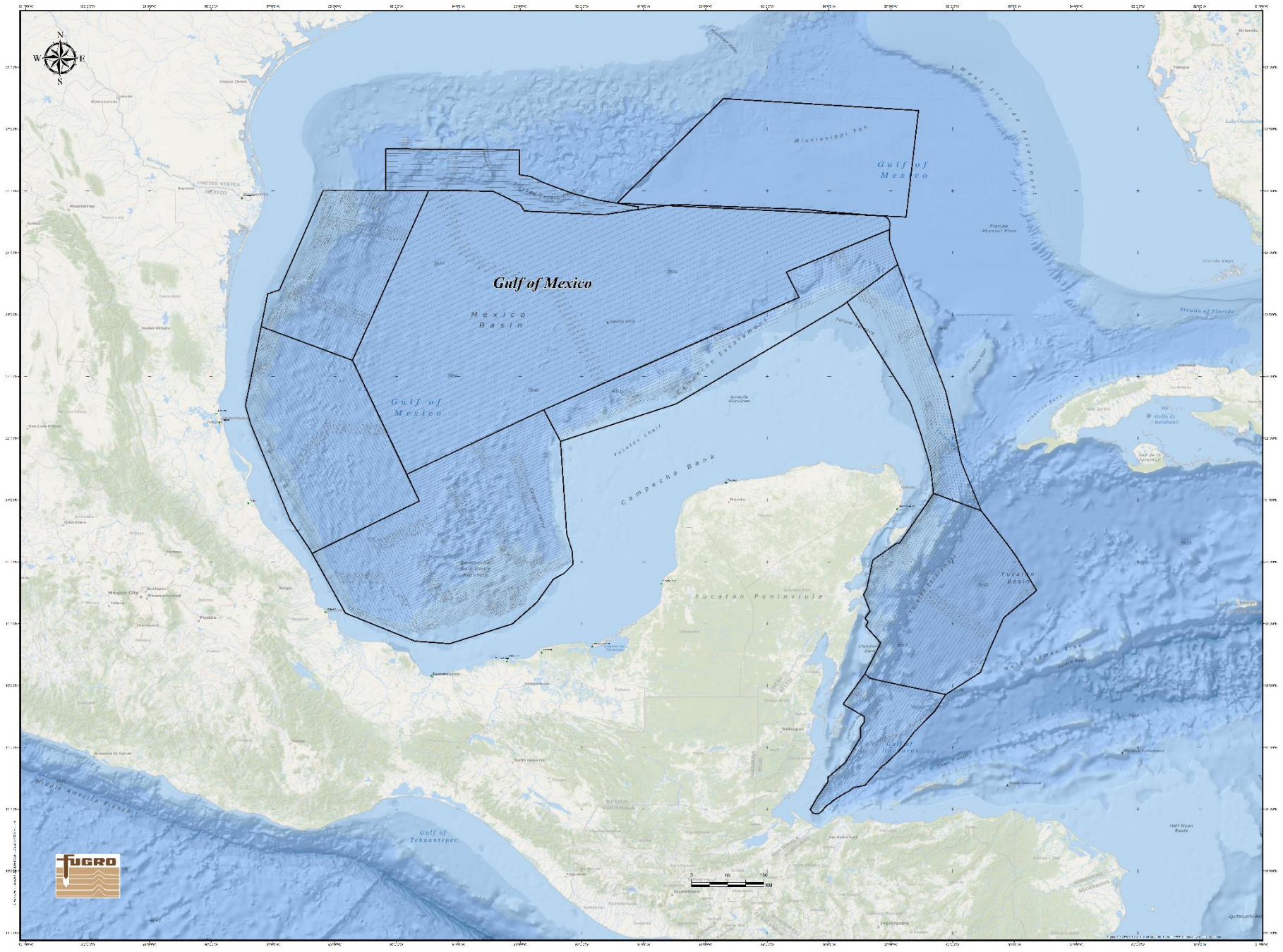
- Fugro to acquire 625,000 km² of multibeam echo sounder data and subbottom profiler data
- Fugro uses the data to identify prime locations to sample for geochemistry



Regions of Fugro-acquired multibeam survey as of 10 Apr 16



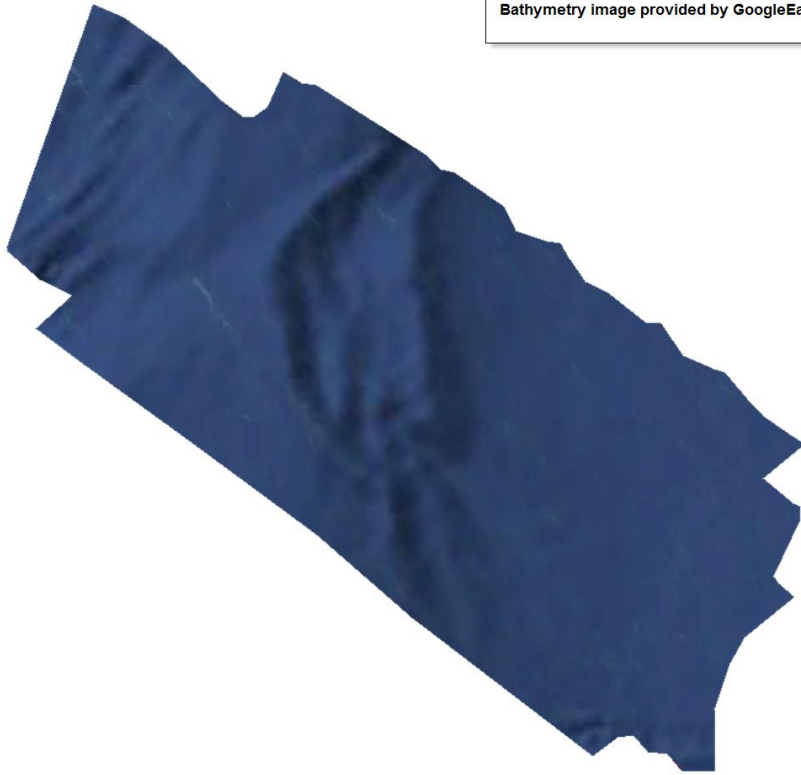
3D view of data from near the survey region



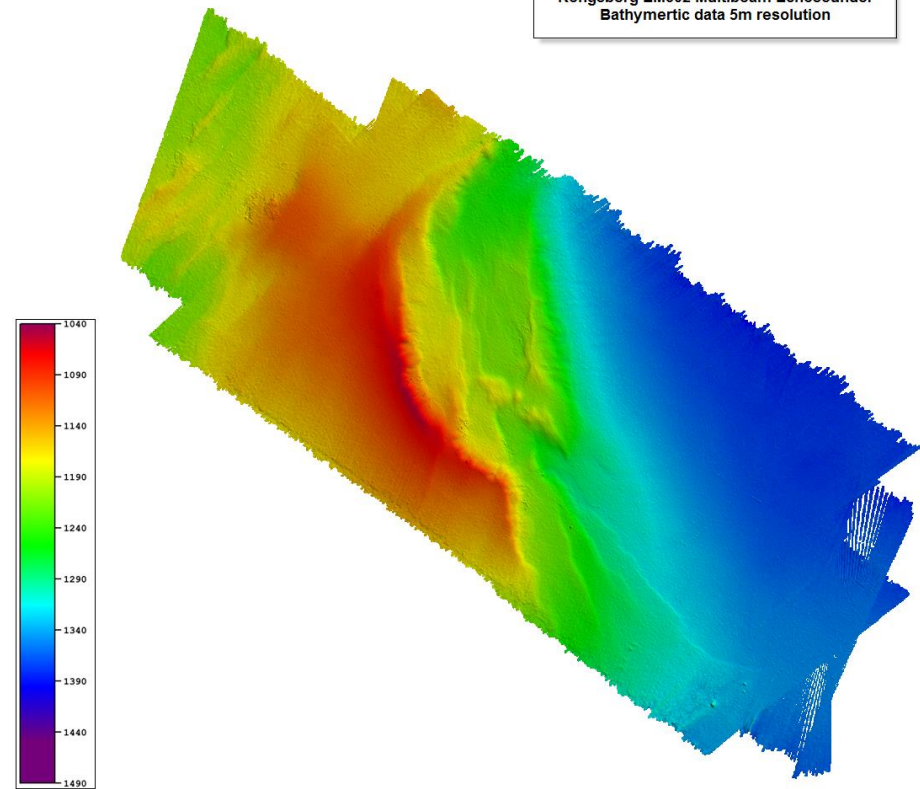
Seabed 2030 – Can Decimated Data be Made Available?



Bathymetry image provided by GoogleEarth



Kongsberg EM302 Multibeam Echosounder
Bathymetric data 5m resolution

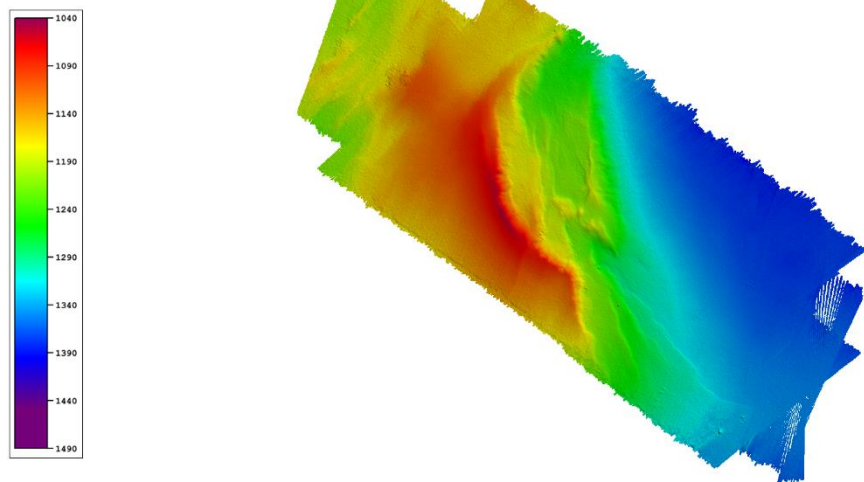


Google Earth

MBES - 5m Grid

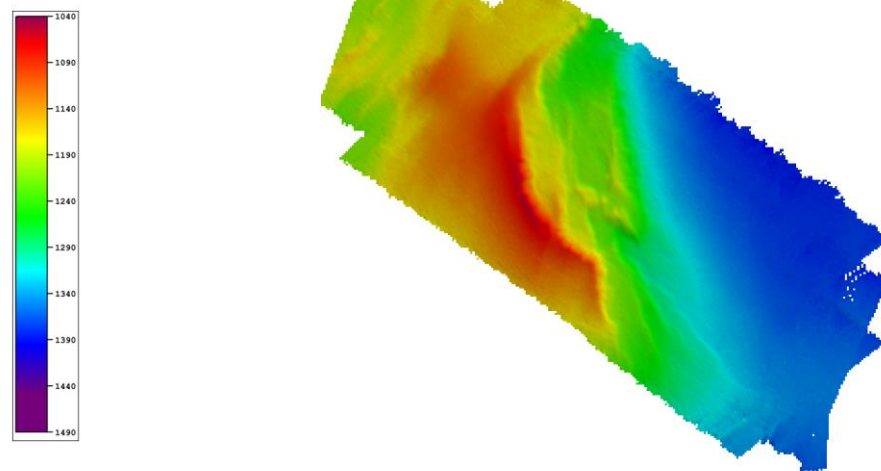
Seabed 2030 – Can Decimated Data be Made Available?

Kongsberg EM302 Multibeam Echosounder
Bathymetric data 5m resolution



MBES – 5m Grid

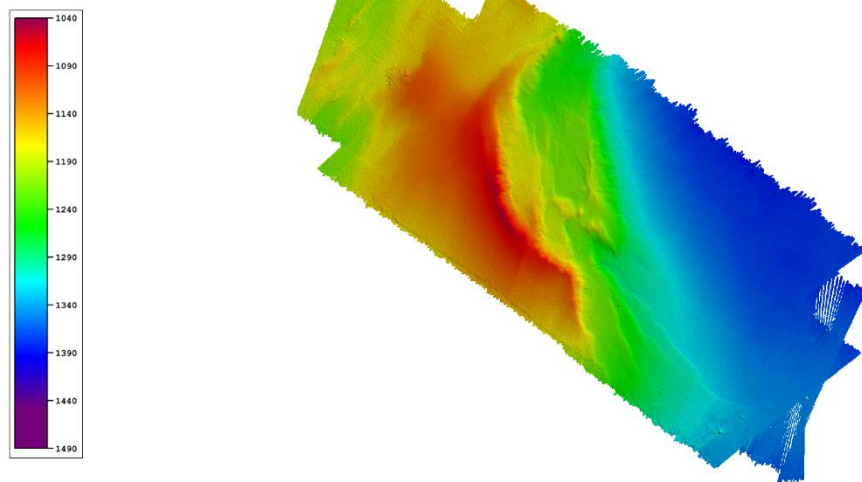
Kongsberg EM302 Multibeam Echosounder
Bathymetric data 50m resolution



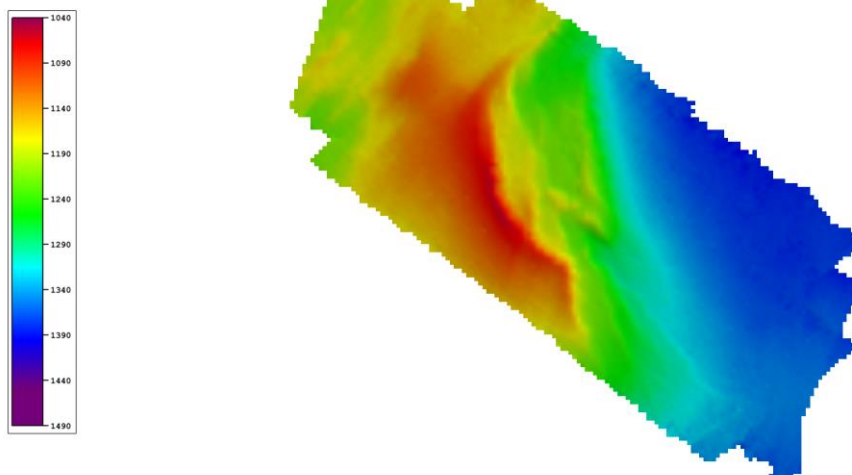
MBES – 50m Grid

Seabed 2030 – Can Decimated Data be Made Available?

Kongsberg EM302 Multibeam Echosounder
Bathymetric data 5m resolution



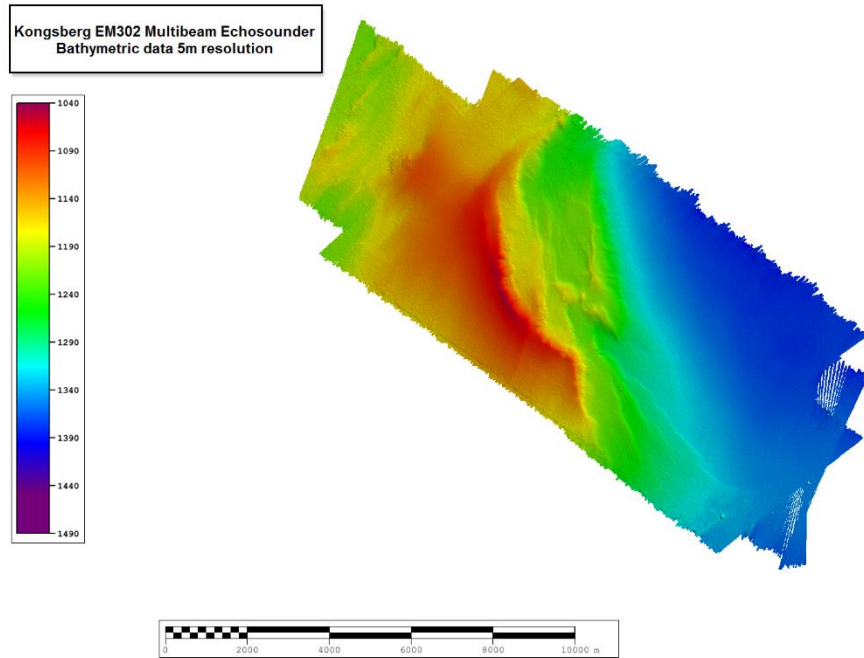
Kongsberg EM302 Multibeam Echosounder
Bathymetric data 100m resolution



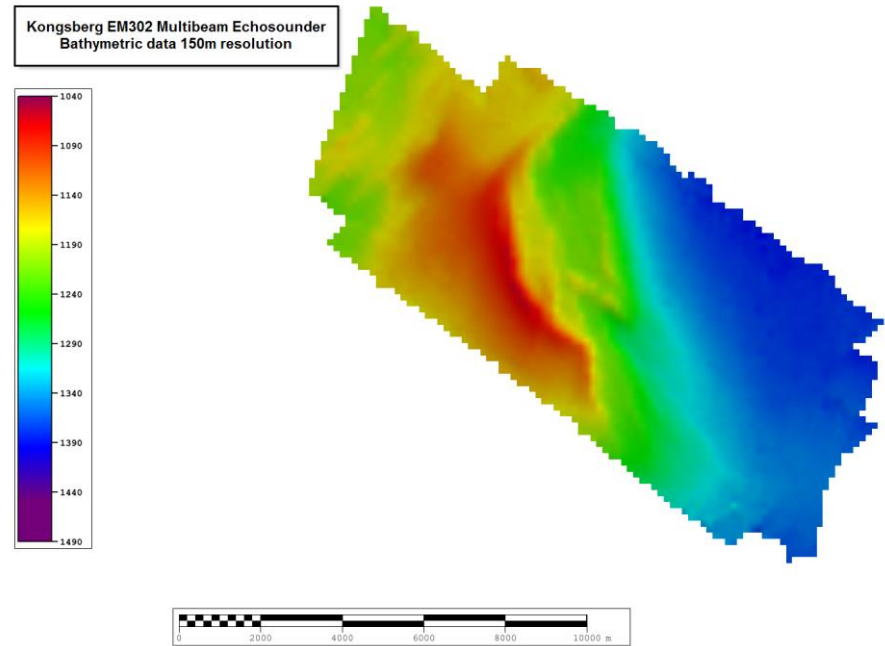
MBES – 5m Grid

MBES – 100m Grid

Seabed 2030 – Can Decimated Data be Made Available?



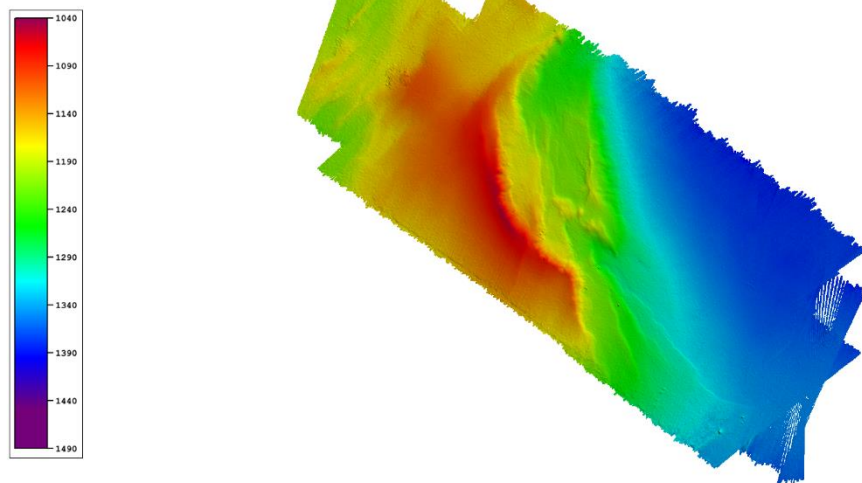
MBES – 5m Grid



MBES – 150m Grid

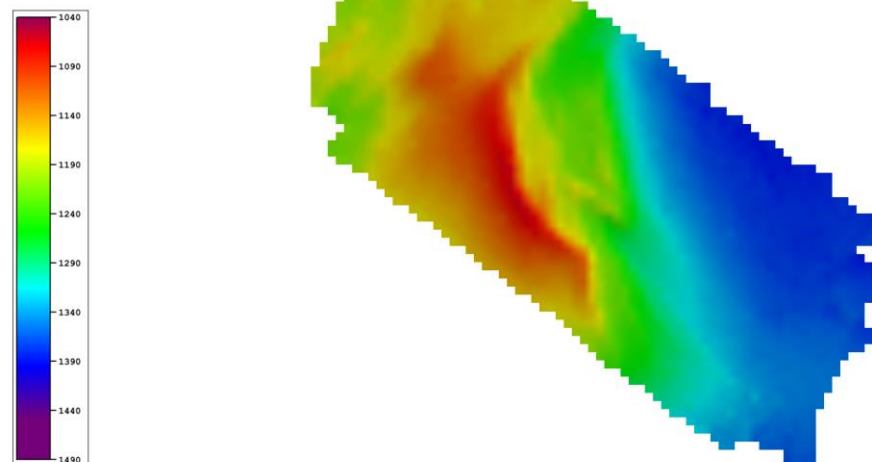
Seabed 2030 – Can Decimated Data be Made Available?

Kongsberg EM302 Multibeam Echosounder
Bathymetric data 5m resolution



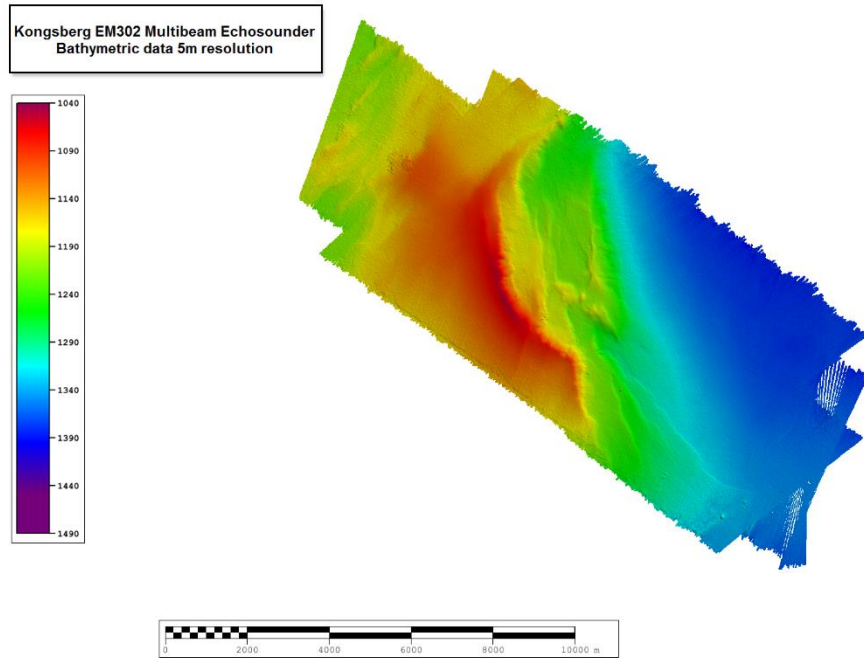
MBES – 5m Grid

Kongsberg EM302 Multibeam Echosounder
Bathymetric data 200m resolution

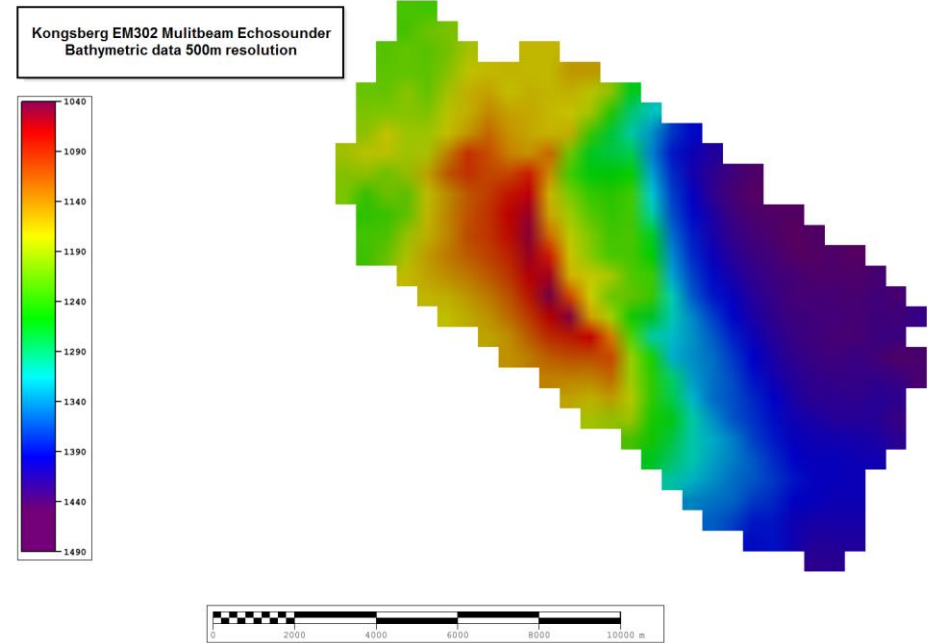


MBES – 200m Grid

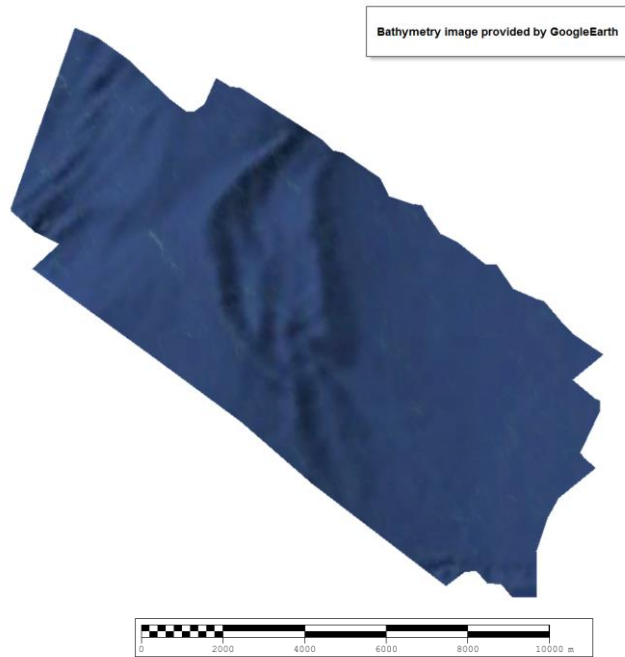
Seabed 2030 – Can Decimated Data be Made Available?



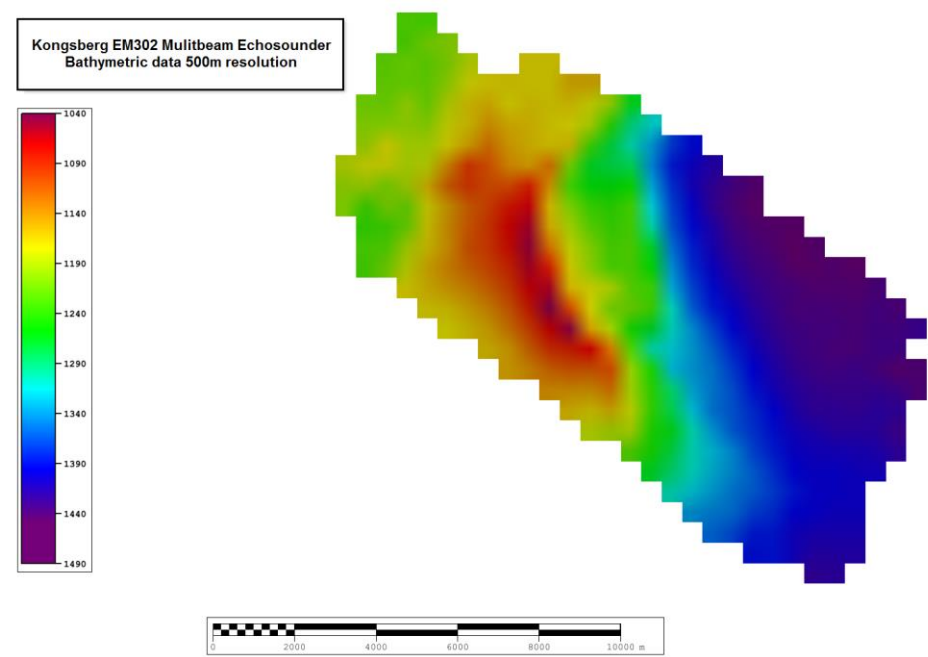
MBES – 5m Grid



MBES – 500m Grid

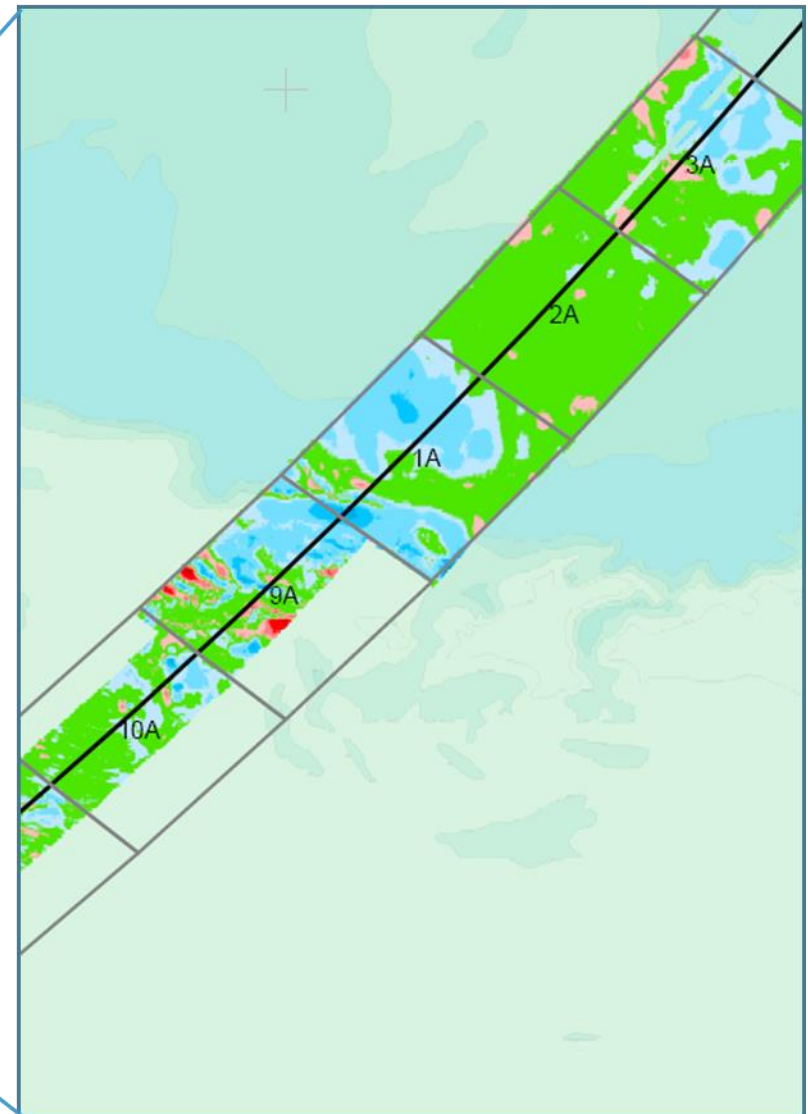
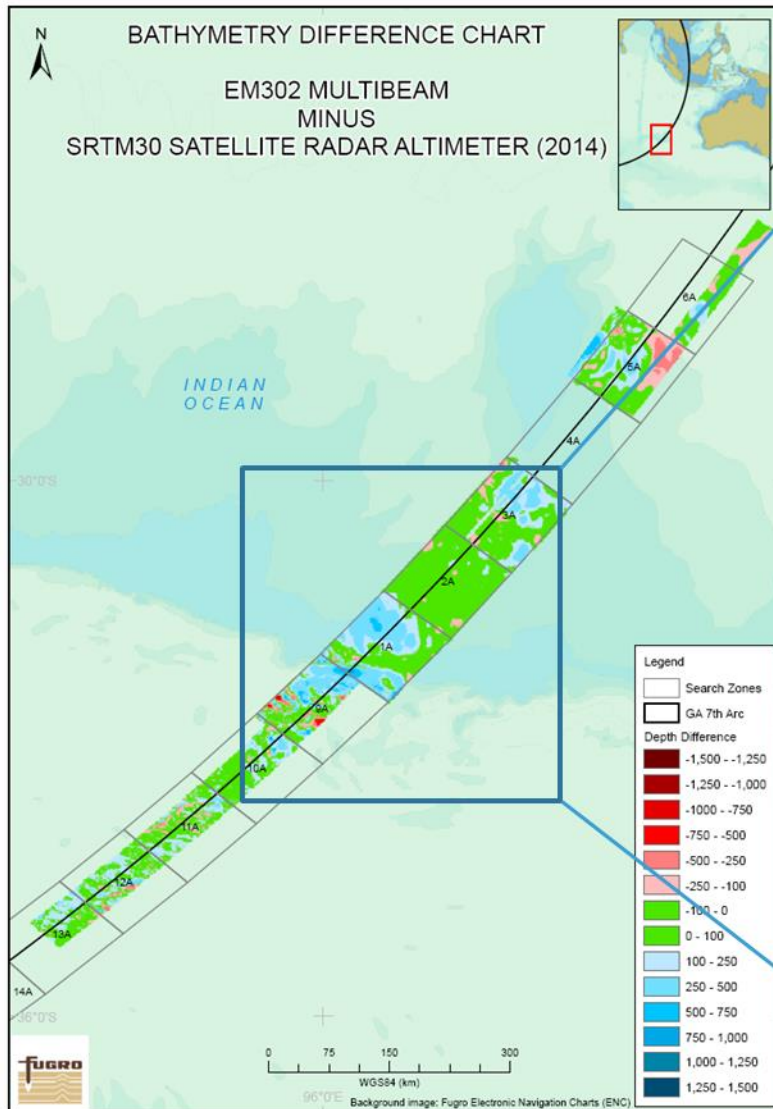


Google Earth



MBES – 500m Grid

Even Decimated Data will Improve Absolute Accuracy





Thank You

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