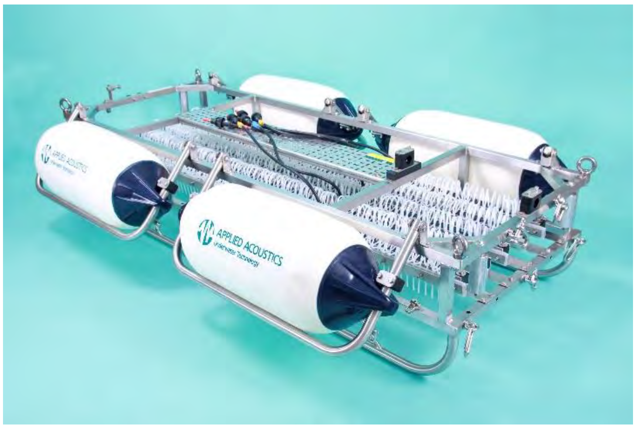
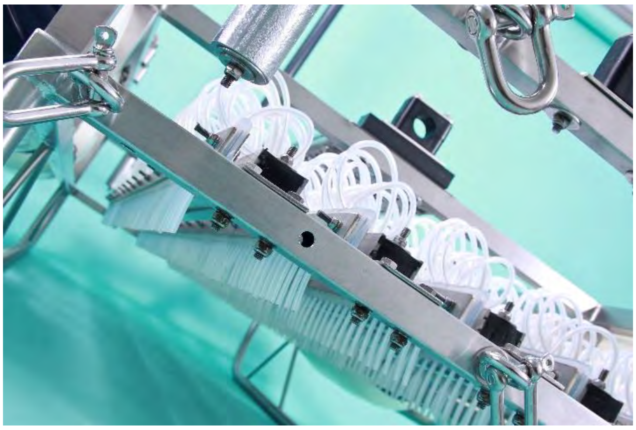
Appendix A

Manufacturer Specifications

Applied Acoustic Engineering Ltd
Marine House, Marine Park, Gapton Hall Road
Great Yarmouth, NR31 0NB
United Kingdom

Dura-Spark UHD, Seismic Sound Source





Key Features

- Long life, durable electrodes
- Pulse stability
- High resolution sub-bottom data, up to 25cms
- Tip array selection from on board junction box
- Flip-flop capability
- GNSS receiver option (101G MiniPod)

Applications

- High and Ultra-High Resolution geophysical surveys
- Single and multi-channel acquisition
- Water depths of 5 to >1000m

The Dura-Spark UHD has been designed to provide a stable, repeatable sound source for sub-bottom geophysical surveys. The long life, durable electrodes produce a consistent pulse signature and keep operational maintenance to a minimum. This provides increased survey efficiency and equipment reliability as the sparker tips rarely need replacement.

The Dura-Spark UHD consists of either 5 or 3 arrays of 80 tips that allow the operator to tune the source from the vessel to its application. This flexibility, together with selectable source depth, allows the sound source to be used in both shallow and deep waters.

The typical operational bandwidth of the Dura-Spark UHD is 300Hz to 1.2kHz. When coupled with the CSP-Nv Seismic Power Supply the system offers 2000J/s peak discharge rate, as well as industry leading design and safety standards.

Dura-Spark UHD Technical Specification

PHYSICAL

Dimensions	Length 1893mm Height 372mm frame, 622mm including floatation Width 650mm frame, 1280mm including floatation
Weight	130kg (max)
Connector	RMK 1/0 complete with locking collar

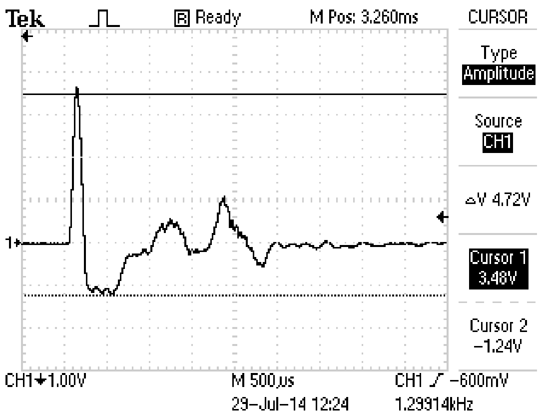
ELECTRICAL

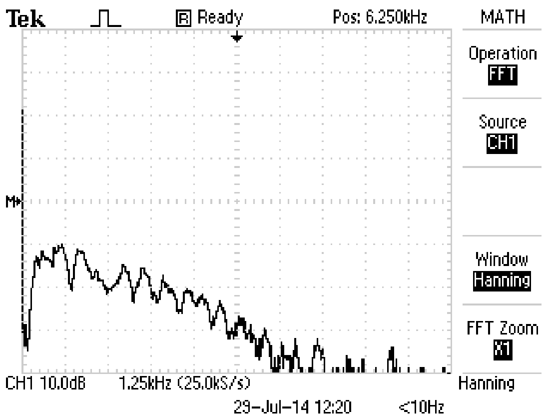
400 tip	2000J, 5J per tip to minimise bubble collapse component, 2400J maximum
240 tip	1000J, 5J per tip to minimise bubble collapse component, 1250J Maximum
Operating voltage	3000-4000V
Maximum number of tips	400 (5 x 80), 240 (3 x 80)
Power supply	CSP-Nv1200, CSP-Nv2400, CSP-SNv1250

SOUND OUTPUT

Source level	226dB re 1µPa at 1m (typical)
Pulse length	0.5 to 1.5ms Dependent on power applied

TYPICAL PULSE SIGNATURES AT 2000J





APPLIED ACOUSTICS
Underwater Technology
An AAE Technologies Group Company

Registration No. QU160081a
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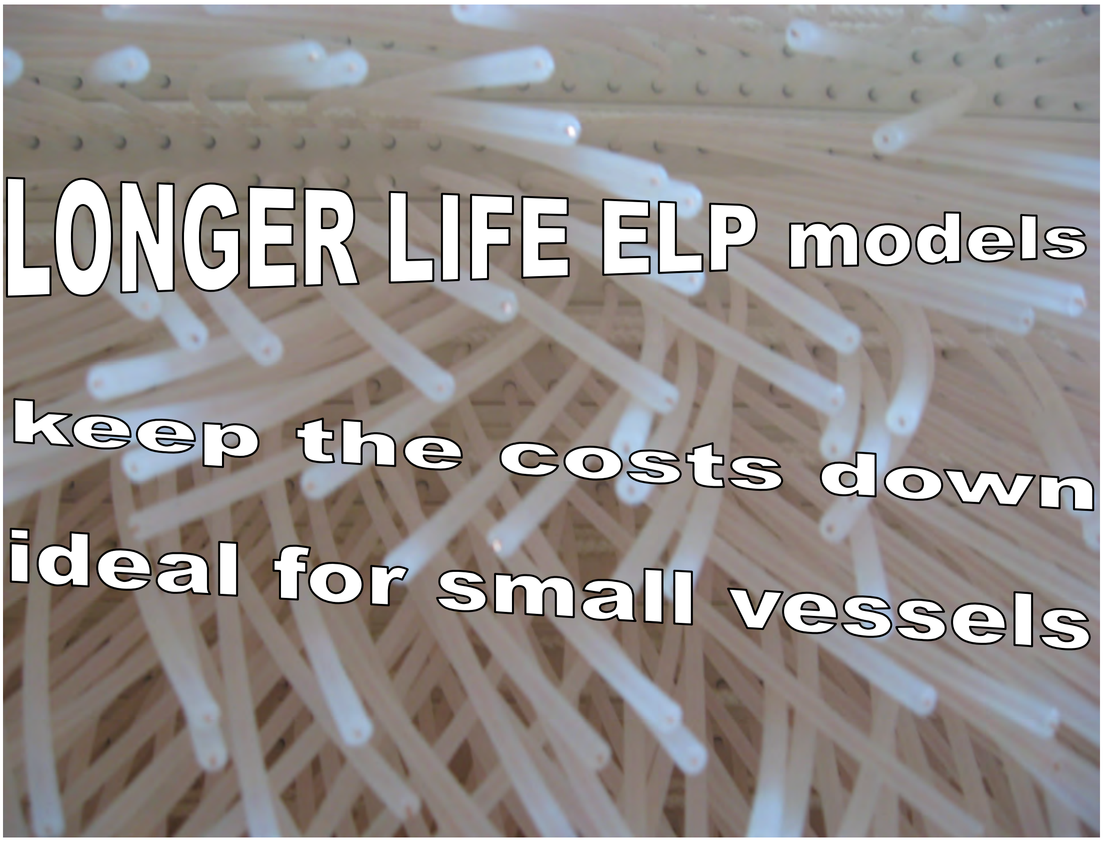
SIG sparker-electrodes

SIG

www.marine-seismic-equipments.com

- Longer life ELP models,
- Floating spark-arrays,
- no catamaran necessary,
- Easily replaceable,
- Interchangeable on the same high voltage tow cable



SIG sparker-electrodes

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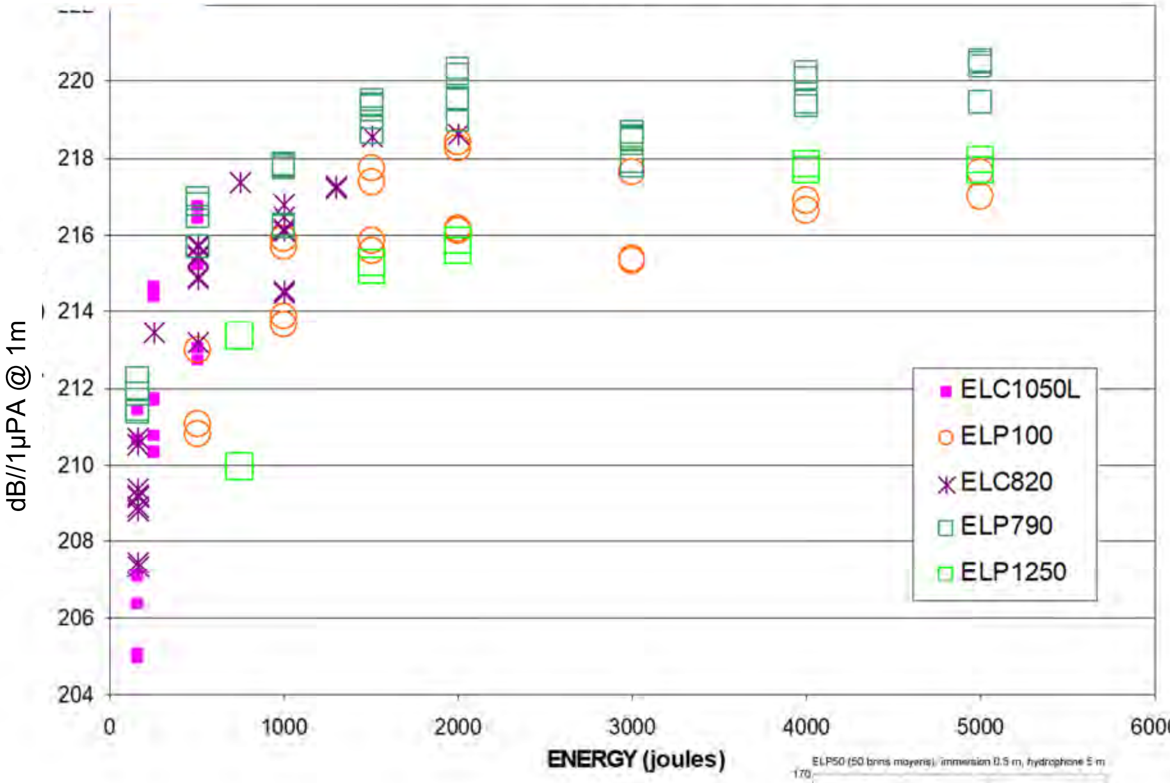
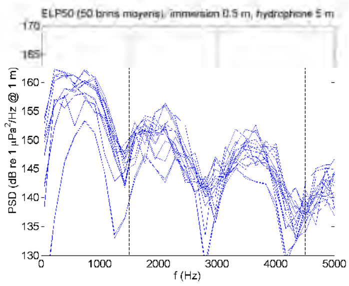
SIG SPARKER-ELECTRODES MODELS

- ELC 1050L
- ELC1200L
- ELC820
- EDL1020
- ELP 790
- ELP1250

Higher frequency	ELC1050L & ELC1200L	ELC820	EDL1020
Operating energy level :	100 to 500 joules	500 to 1000 joules	400 to 2000 joules
Frequency spectrum :	1000—1400 Hz	900—1400 Hz	900—1400 Hz
Acoustic power level :	217 dB re 1µPa @ 1 m	219 dB re 1µPa @ 1 m	220 dB re 1µPa @ 1 m
Pulse duration :	0.8 ms @ 250 J Immersed 20 cm	0.8 ms @ 750 J Immersed @ 20 cm	1.1 ms @ 1500 J, Immersed @ 40 cm
Dimensions :	0.50 m x 0.60 m x 0.04 m	1 m x 0.60 m x 0.04 m	1 m x 0.60 m x 0.06 m
Weight :	1.0 kg	1.8 kg	3.5 kg





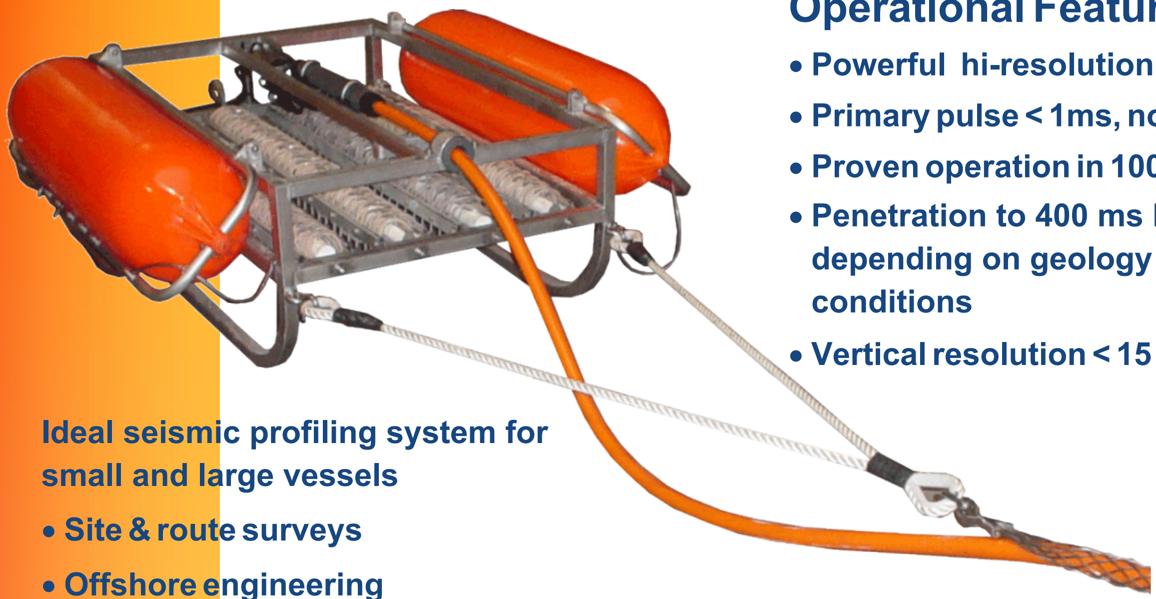
ELP SERIES

COMPROMISE BETWEEN THE LOW COST AND THE NECESSARY TRIMMING
THE ELP SERIES IS LONGER LIFE

Lower frequency	ELP790	ELP1250
Operating energy level :	100 to 3000 joules Optimal 400-1200 joules	1000 to 6000 joules Optimal 1600 joules
Frequency spectrum :	< 800 Hz after 1000 J @ 50cm	Centered 1200 Hz @ 30cm
Acoustic power level :	220 dB re 1µPa @ 1 m	216-218 dB re 1µPa @ 1 m
Pulse duration (immersed @ 30 cm)	Primary 1.18 ms @ 500 J Delta T secondary 2.9 ms @ 1000 J	Primary 1.27 ms @ 2000 J Delta T secondary 2.8 ms @ 4000 J
Dimensions :	1 m x 0.60 m x 0.06 m	1 m x 0.60 m x 0.06 m
Weight :	2 kg	5.2 kg

Geo-Source 200 - 400

Marine Multi-Tip Sparker System



Operational Features

- Powerful hi-resolution seismic source
- Primary pulse < 1ms, no ringing
- Proven operation in 1000 m water depth
- Penetration to 400 ms below seabed, depending on geology and survey conditions
- Vertical resolution < 15 cm

Ideal seismic profiling system for small and large vessels

- Site & route surveys
- Offshore engineering
- Mineral exploration
- Oceanographic research

INNOVATIVE Preserving Electrode Mode

The innovative Geo-Source 200 has been designed for operation with the Geo-Spark 1000 pulsed power supply (PPS) using the patented **Preserving Electrode Mode.** This mode uses a NEGATIVE electric discharge pulse instead of a positive pulse.

(Please note that this negative pulse is NOT the same as the simple reversal of the positive polarity of a 'standard' power supply.)

Maintenance free electrodes 5 year guarantee

The Preserving Electrode Mode **reduces the tip wear to practically zero**. You can shoot day after day, week after week, month after month with practically **NO tip maintenance.**

Always a stable acoustic pulse

Zero tip wear is essential for the **acoustic repeatability** of the pulse, which depends largely on a constant, unaltered electrode surface and tip insulation.

Efficient & Cost Effective

With the Geo-Spark HV power supplies you will save a lot of time and money, since the electrodes do NOT burn off like in all other systems.

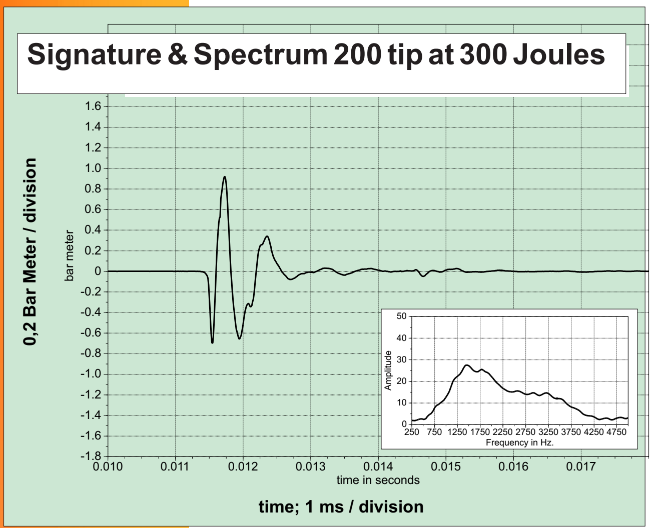
You don't need to trim tips during the survey. There is no need to have any stock of consumables.

Examples of Records

To see examples of our sparker records, please visit the 'Downloads' page on our website: ***www.geo-spark.com***

Geo-Source 200-400

Technical Specifications



Maintenance free electrodes, no trimming, stable signature

Electrodes Geometry

The electrode modules are evenly spaced in a planar array of 0.75 m x 1.00 m. This geometry not only enhances the downward projection of the acoustic energy, it also reduces the primary pulse length, since all tips are perfectly in phase.

Control of Source Parameters 200 - 400 tips

The advanced Geo-Source 200-400 design gives you total control of the source depth and the energy (Joules) per tip

Source depth

Two floats provide a stable towing configuration and insure the proper depth of the electrode tips. This is critical to achieve constructive interference between the primary pulse and its own sea-surface reflection (surface ghost)

Number of tips in use and Energy per tip

Four individually powered electrode modules of 50 or 100 tips each allow you to distribute the energy from the Geo-Spark power supply over 50, 100......, up to 400 tips. (Each tip has an exposed surface area of 1.4 mm^2.)

200 tips, the classic 200 tip configuration is normally used with the Geo-Spark 1000 PPS and consists of four 50-tip electrode modules. This configuration gives an excellent hi-res pulse over the 100 to 500 J power range.

400 tips, for higher energies above 1000 J, and in particular with the Geo-Spark 2000X, we recommend a 400 tip configuration with 4 x 100-tip electrode modules

Coaxial High Voltage (HV) Power/Tow Cable

The Geo-Source 200 is towed by a very high quality, Kevlar-reinforced, coaxial power/tow cable with stainless steel kellum grip. This dedicated high voltage (HV) cable contains **4 x 10 mm^2** inner cores (negative) plus a **40 mm^2** braiding (ground-referenced). It is designed to have a very low self-inductance to preserve the high dI/dt pulse output of the Geo-Spark 1000 PPS.

The coaxial structure of the HV cable reduces the electromagnetic interference to the absolute minimum.

The wet end of the cable is terminated with four special HV connectors to the electrode modules and a ground connector to the frame. Connecting or disconnecting the cable to the Geo-Source 200 takes only 10 minutes; so you can handle the sparker sled and the HV cable as independent units.

The dry end of the cable is terminated at the Geo-Source 200 patch panel, which allows you to select the number of electrode arrays in use

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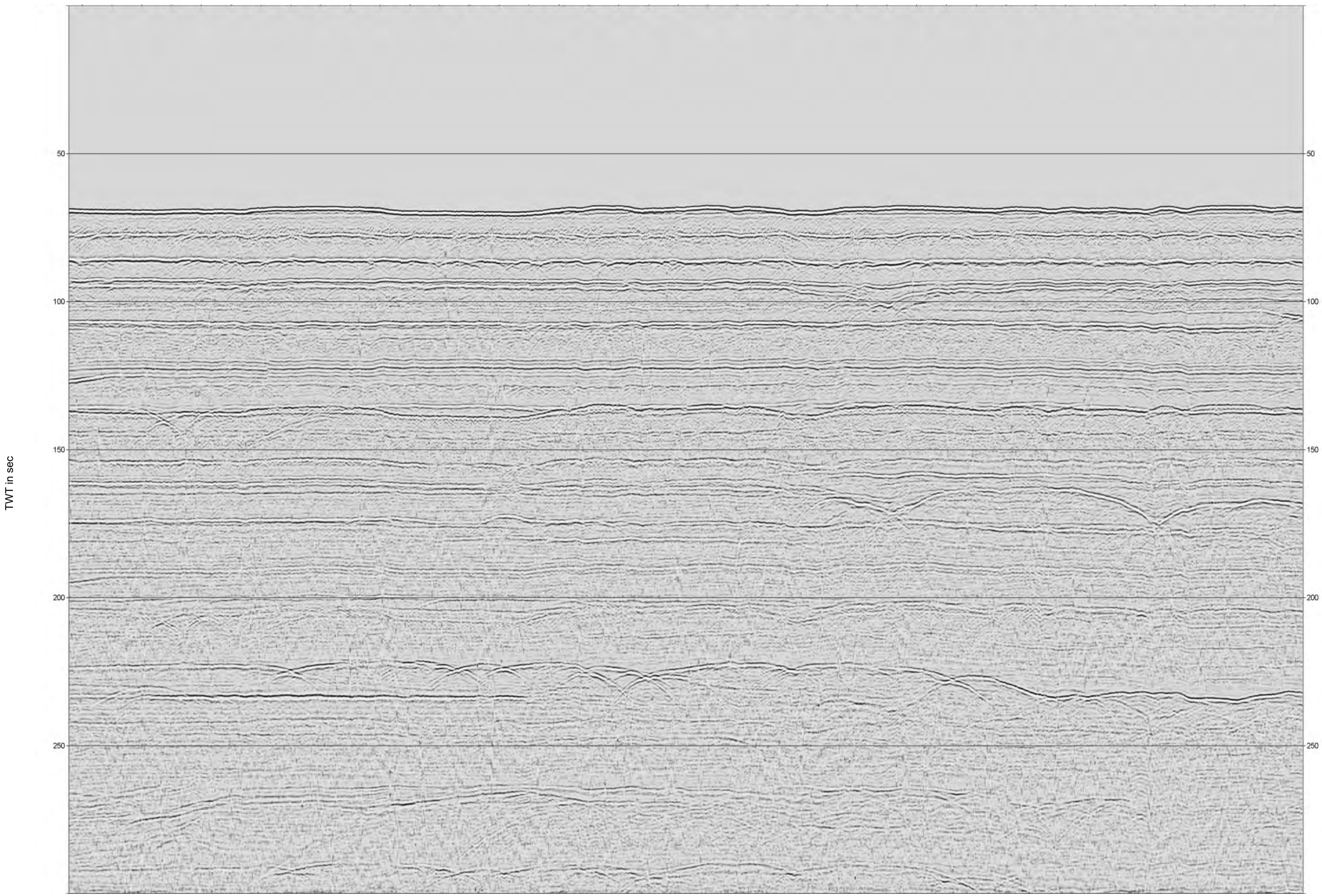
The Netherlands
Phone: + 31 10 41 55 755
Fax: +31 10 41 55 351
info@geomarinesurveysystems.com
Website: www.geo-spark.com



Location: Thailand

Date: August 2008

Client: MVM Surveys

Water Depth: 50 - 300 m

Acquisition

Source: Geo-Spark 200
Power Supply: Geo-Spark 1 kJ
Power: 300 J
Streamer: Geo sense
Recording System: Geo-Trace 2
Shot interval: 0.5 s
Record length: 300 ms
Sample Rate: 8000 Hz

Processing

Frequency filtering
Gain
Swell filter
Muting

Display

Horizontal scale 1:4000
Vertical scale 1 cm = 8 ms
One timeline every 50 ms

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3023 CD Rotterdam
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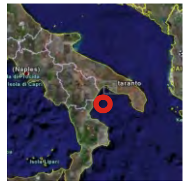
Geo-Spark 200 Thailand- August 2008

Alternating sand and clay layers.
Strong reflector at the base of layer turbiditic sequence
represents the top of Messinian evaporites.

Taranto Italy - May 2005



Location: Taranto Italy

Date: May 2005

Client: Nautilus

Water Depth: 450 - 650 m

Acquisition

Source: Geo-Spark 200
Power Supply: Geo-Spark 1 kJ
Power: 700 J
Streamer: Geo-sense 8 elements
Recording System: Geo-Trace 2
Shot interval: 3 s
Record length: 1500 ms
Sample Rate: 8000 Hz

Processing

Frequency filtering
Gain
Swell filter
Muting

Display

Horizontal scale 1:12000
Vertical scale 1 cm = 15 ms
One timeline every 50 ms

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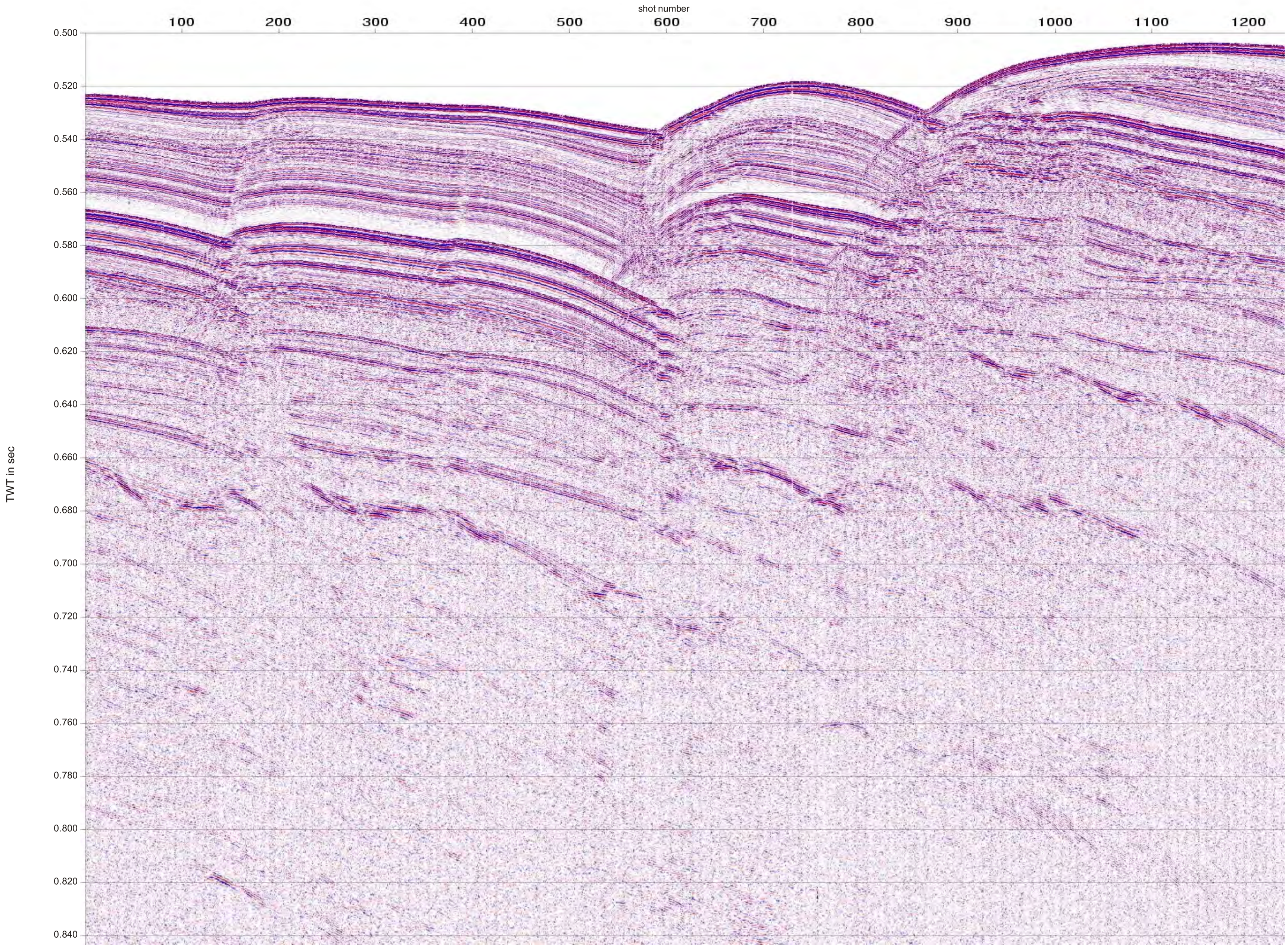
Approximately 500m



Mediterranean Sea Egypt , October 2005

GEO RESOURCES

Location: Mediterranean Sea, Egypte

Date: October 2005

Client : Impresub

Water Depth: 350 - 400 m

Acquisition

Source: Geo-Spark 200
Power Supply: Geo-Spark 1 KJ
Streamer: Geo sense 8 elements
Recording System: Geo-Trace 2
Shot interval: 2 s
Record length: 1000 ms
Sample Rate: 10000 Hz

Display

Horizontal scale 1:9000
Vertical scale 1 cm = 10 ms
One timeline every 20 ms

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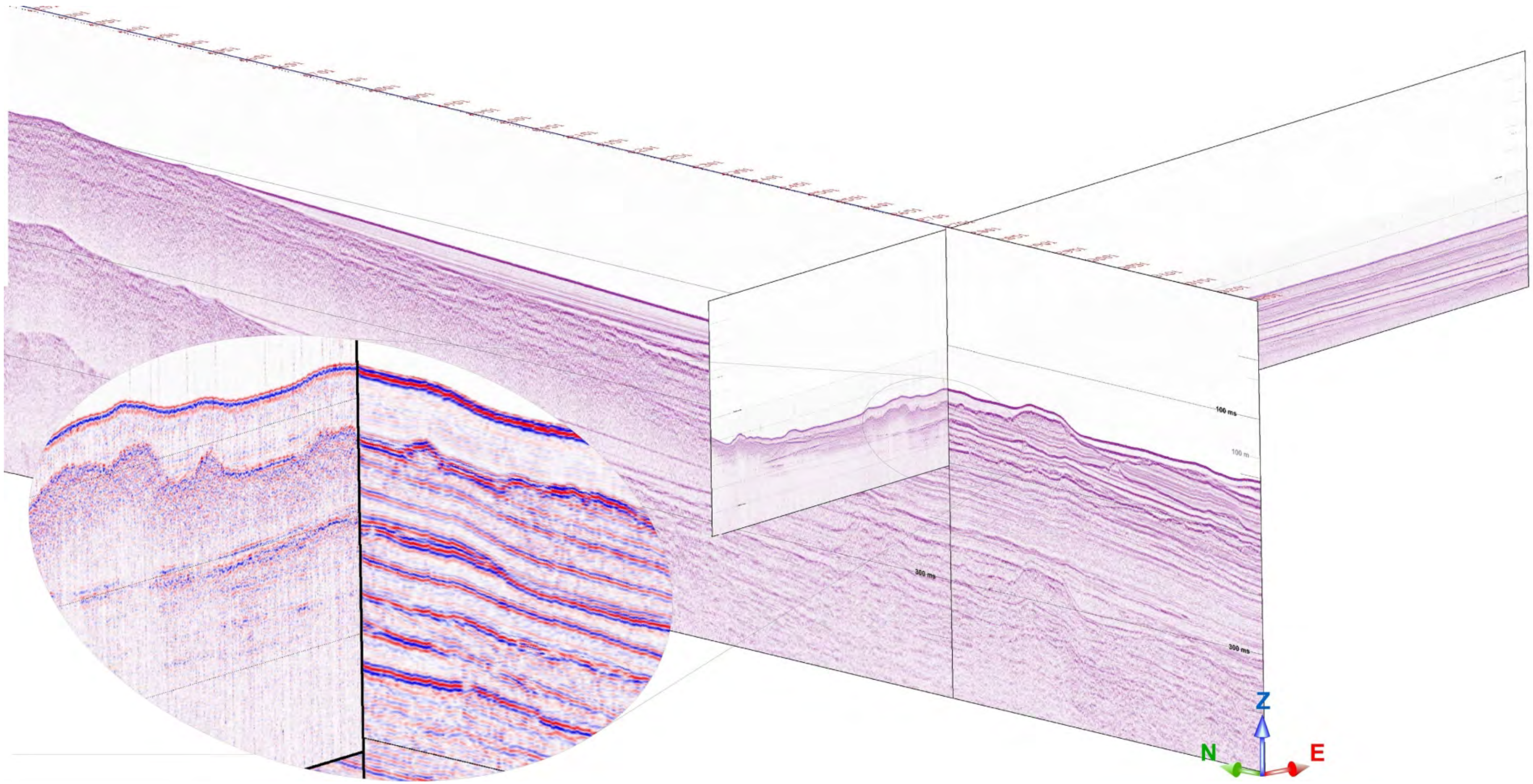
Approximately 500m

Comparison between the Sparker Geo-Spark 800 and a Chirp system.

Appreciate the difference of resolution and penetration.



Location: Elba Italy

Date: November 2004

Water Depth: 75 - 115 m

Courtesy of Danillo Morelli, Trieste University

Acquisition

Source: Geo-Spark 800
Power Supply: Geo-Spark 6 kJ
Recording System: Geo-Trace 2
Shot interval: 2 s
Record length: 1000 ms
Sample Rate: 6000 Hz

Sparker Processing

Frequency filtering
Gain
Swell filter
Muting

Display

Horizontal scale 1:5000
Vertical scale 1 cm = 25 ms
One scale line every 100 ms
Data displayed in 3D with OpendTect

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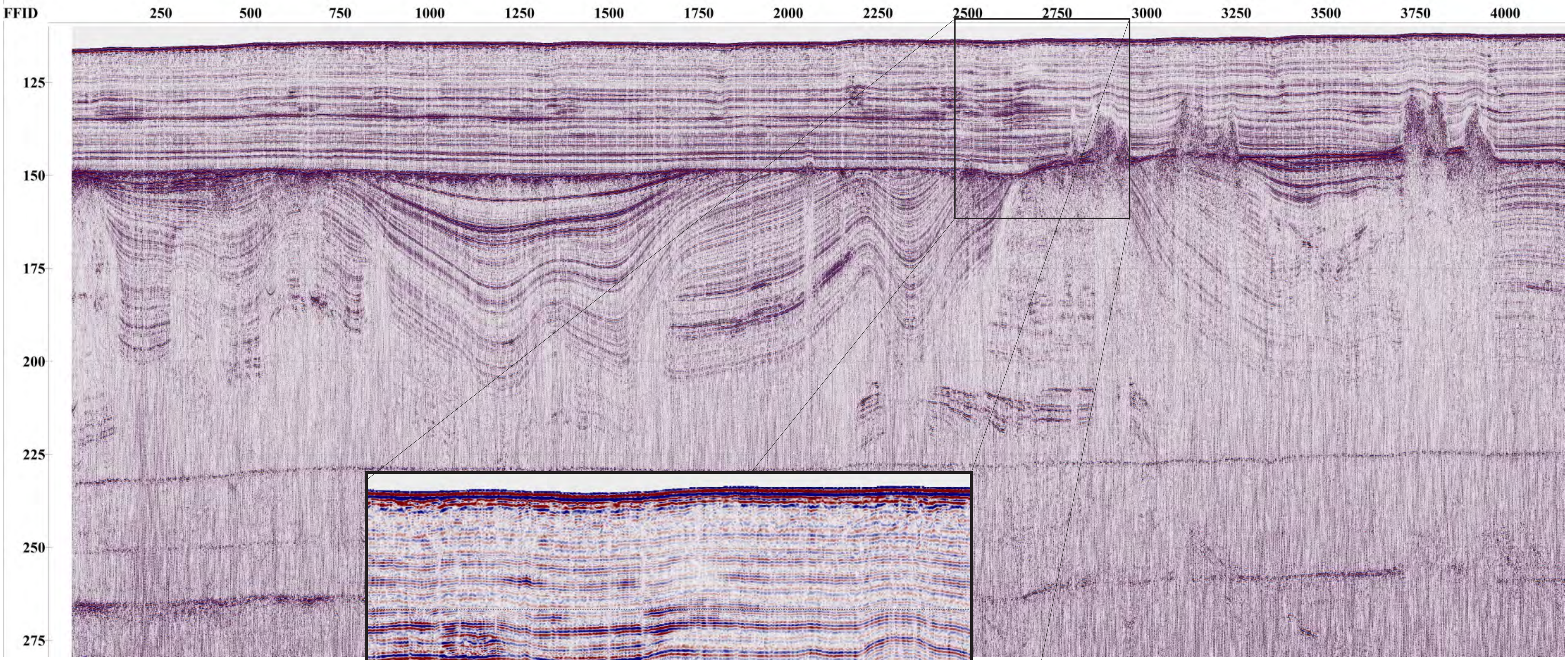
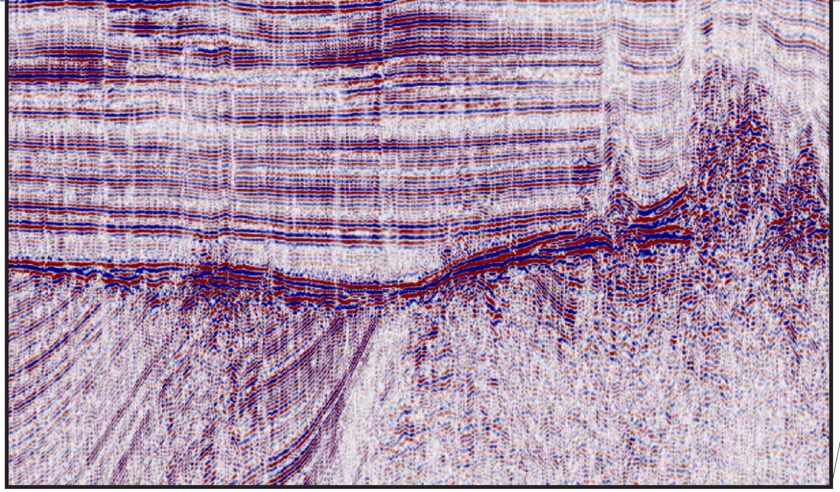
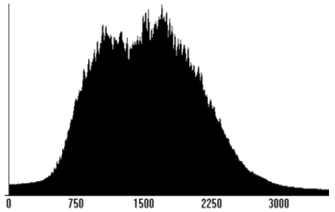
Elba Italy - November 2004

Approximately 200m

M03







Appreciate the frequency content up to 3000 Hz and the decimeter scale resolution

Sparker profile shot with the Geo-Source 200 LW using the Geo-Spark 1000 pulsed power supply

Energy: 300 J, Negative Discharge Technology

Vertical Scale in meters, Aspect ratio 1 :20

Location: Sicily, Gellasabbia
Date: May 2012
Geophysicist: Dr. Henrique Duarte

Geo-Source 400 Light Weight

Dimensions (cm) & Weight	110 (L) x 120 (W) x 60 (H) for 80 kg
Tips Number	400
Operation Depth (m)	0 - 2,500
Dominant Frequencies	1000-1500 Hz (at 800 Joules)
Compatible Power Supply	Geo-Spark 1000 Geo-Spark 2000 XF Geo-Spark 7000 XF

2.1.2 Processor Unit Specs

The specifications for the Processing Unit within the rack mount topside are shown in TABLE 2-2.

SPECIFICATION	VALUE
Mother Board	Intel I7 6700 Quad Core 3.4GHz. 8 MB Cache
Sonar Interface	Sonar Interface board (Tiger board) composed of carrier board, Acquisition board, and Sonar board
Memory	8 GB DDR4 RAM
Hard Drives	500 GB minimum (operating system) 1 TB minimum (Removable Drive [Hot Swappable])
DVD-R/W drive	10x4x32 minimum speed
Operating system	Windows 7 64 Bit
Application software	DISCOVER Sub-Bottom
Display	High resolution 23-inch flat panel LCD monitor
Keyboard	High impact industrial
Trackball	High impact industrial
I/O ports	(4) RS-232 Front: (2) Ethernet Ports (2) USB2 Rear: (2) USB2 (2) USB3 (2) USB3.1
Analog input	16-bit resolution, 200 kHz max sampling rate
Analog Output	16-bit resolution, 200 kHz max sampling rate
Pulse type	Full Spectrum CHIRP FM
Pulse length	5-100 ms, depending on tow vehicle and application
Bandwidth	0.5-15 kHz, depending on tow vehicle and application
Trigger in	TTL negative edge triggered
Trigger out	TTL negative edge triggered, 5ms ling pulse minimum
Sampling rate	20, 25, 40, or 50 kHz, depending on the transmit upper frequency
Acoustic power	212 dB re1 NPa @ 1 meter peak (approx.) at center frequency
Input voltage	120-220 VAC, 50/60 Hz, auto sense

Table 2-2: 3200-XS Topside Processor Specs

2.1.3 Power Amplifier

The specifications for the Power Amplifier are show in TABLE 2-5, TABLE 2-4, and TABLE 2-5.

2.1.3.1 Power Output

SPECIFICATION	VALUE
2-ohm Dual (*per channel*)	20 mS BURST: 4,700 W 20 Hz – 20 kHz: 2,800 W 1 kHz: 2,800 W
4-ohm Dual (*per channel*)	3,500 W
8-ohm Dual (*per channel*)	1,500 W
4-ohm Bridge	5,600 W
8-ohm Bridge	6,000 W

Table 2-3: Power Amplifier Specs: Power Output

EdgeTech

2000 SERIES

COMBINED SIDE SCAN SONAR & SUB-BOTTOM PROFILING SYSTEM

KEY SPECIFICATIONS

SIDE SCAN SONAR		
Frequency (dual simultaneous CHIRP)	100/400 kHz	300/600 kHz
Operating Range	100 kHz: 500 meters/side 400 kHz: 150 meters/side	300 kHz: 230 meters/side 600 kHz: 120 meters/side
Beam Width (2-way) & Along Track Resolution	100 kHz: 1.08 deg or 1.90 m @ 100 m 400 kHz: 0.56 deg or 0.96 m @100 m	300 kHz: 0.6 deg or 1.0 m @ 100 m 600 kHz: 0.26 deg 0.45 m @ 100 m
Across Track Resolution	100 kHz: 6.3 cm 400 kHz: 1.8 cm	300 kHz: 2.8 cm 600 kHz: 1.4 cm

SUB-BOTTOM PROFILER	2000-CSS	2000-DSS	2000-TVD
Frequency Band	500 Hz – 12 kHz	2-16 kHz	1-10 kHz
Resolution	8-20 cm	6-10 cm	9-25 cm
Penetration in coarse sand	20m	6m	20m
Penetration in clay	200m	80m	200m
TOWFISH	**2000-CSS**	**2000-DSS**	**2000-TVD**
Length	160 cm (63")	145 cm (57")	226 cm (89")
Width	124 cm (49")	74 cm (30")	81 cm (32")
Height	47 cm (18.5")	84 cm (33")	55 cm (22")
Weight in Air	232 kg (510 lbs.)	145 kg (320 lbs.)	250 kg (550 lbs.)
Maximum Water Depth	300m	2,000m	3000m

TOPSIDE PROCESSOR	
Hardware	Standard 19" rack
Operating System	Windows XP
Display	Dual 22" high resolution flat panel monitors
Archive	DVD-R/W and/or LAN connection
File Format	Native JSF or XTF for side scan, SEG-Y for sub-bottom
Output	Ethernet
Power Input	90 to 132 VAC and 180 to 260 VAC, Auto voltage detect and switching, 47-63 Hz

For more information please visit EdgeTech.com

info@EdgeTech.com | USA 1.508.291.0057

SPECIFICATION	SB-424 VALUE	SB-216S VALUE	SB-512i VALUE
Frequency range	4-24 kHz	2-16 kHz	0.5-12 kHz
Pulse type	FM	FM	FM & WB (wide band)
Pulse bandwidth/pulse length	4-24 kHz/10 ms 4-20 kHz/10 ms 4-16 kHz/10 ms	2-15 kHz/20 ms 2-12 kHz/20 ms 2-10 kHz/20 ms	0.5-8.0 kHz/5 ms FM 0.5-2.7 kHz/40 ms WB 0.5-6.0 kHz/20 ms WB 0.5-4.5 kHz/50 ms FM 0.5–6.0 kHz/9 ms FM 0.5–6.0 kHz/18 ms FM 0.5–7.2 kHz/30 ms FM 0.7–12.0 kHz/20 ms FM 2.0–12.0 kHz/20 ms FM
Calibration:	Gaussian-shaped pulse spectrum	Gaussian-shaped pulse spectrum	Gaussian- and rectangular-shaped pulse spectrum
Vertical resolution[a]	4 cm (4–24 kHz) 6 cm (4–20 kHz) 8 cm (4–16 kHz)	6 cm (2–15 kHz) 8 cm (2–12 kHz) 10 cm (2–10 kHz)	19 cm (1–5.0 kHz) 12 cm (1.5–7.5 kHz) 8 cm (2–12 kHz)
Penetration in course and calcareous sand[b]	2 m (typ)	6 m (typ)	30 m (typ)
Penetration in soft clay[b]	40 m	80 m	250 m
Beam width	16°, 4–24 kHz 19°, 4–20 kHz 23°, 4–16 kHz	17°, 2–15 kHz 20°, 2–12 kHz 24°, 2–10 kHz	41°, 0.5–5 kHz 32°, 1–6 kHz 24°, 1.5–7.5 kHz 16°, 2–12 kHz
Optimum tow vehicle pitch/roll[c]	<7°, 4–24 kHz <8°, 4–20 kHz <10°, 4–16 kHz	<7°, 2–15 kHz <8°, 2–12 kHz <10°, 2–10 kHz	<16°, 0.5–5 kHz <13°, 1–6 kHz <10°, 2–8 kHz <8°, 2–10 kHz <7°, 2–12 kHz
Optimum tow height	3-5m above sea floor	3-5 m above sea floor	3-5 m above sea floor
Transmitters	1	1	2
Receive arrays	2	2	4
Output power	2000 W	2000W	2000 W
Tow vehicle size	77 cm (30 in.) L 50 cm (20 in.) W 34 cm (13 in.) H	105 cm (41 in.) 67 cm (26 in.) W 46 cm (18 in.) H	158 cm (62 in.) L 134 cm (53 in.) W 46 cm (18 in.) H
Shipping container size	91 cm (36 in.) L 66 cm (26 in.) W 64 cm (25 in.) H	117 cm (46 in.) L 79 cm (31 in.) W 61 cm (24 in.) H	173 cm (68 in.) L 137 cm (54 in.) W 71 cm (28 in.) H
Weight in air	35 kg (78 lb)	72 kg (160 lb)	186 kg (410 lb)
Shipping weight	110 kg (243 lb)	162 kg (357 lb)	356 kg (783 lb)
Tow cable requirements	3 shield-twisted wire pairs	3 shield-twisted wire pairs	3 shield-twisted wire pairs
Depth rating	300 m (984 ft) max	300 m (984 ft) max	300 m (984 ft) max

Table 2-6: Tow Vehicle Specifications

pangeosubsea
sounding out risk

Sub-Bottom Imager™ Sound Source Analysis

for

Information

January 5, 2015

RPT-04563-1

Table of Contents

1 PURPOSE OF DOCUMENT

The purpose of this document is to summarize sound level information pertaining to the Sub-Bottom Imager™ (SBI) high frequency (HF) acoustic projectors, which are operated from a moving platform such as an ROV or vessel. This document will serve as a basis for sound source verification as may be requested by clients.

2 MEASUREMENT APPROACH

In this document, distances to Sound Pressure Level (SPL) and Sound Exposure Level (SEL) isopleths were estimated assuming spherical and cylindrical spreading, where appropriate. This approach does not consider variations in sound propagation due to the geoacoustic properties of the seabed as well as hybrid models.

The Sub-Bottom Imager™ is operated at a nominal elevation of 3.5m (±0.5m) above the seafloor from a moving platform such as an ROV or an over-the-side mounting on a vessel for shallow water applications (i.e. <10m water depth). In this analysis, the acoustic sources are assumed to be omni-directional point sources; the beam pattern of each acoustic projector was not taken into consideration. As such, this analysis is therefore a worst-case approach given that the source does have directionality. All Source Levels (SL) from transducers are assumed to be levels that would occur directly under the transducers in the direction of the seabed (peak of main lobe). The transducer face is assumed to be at the normal elevation of 3.5 m above the seabed.

3 SUB-BOTTOM IMAGER™ SYSTEM AND ACQUISTION PRINCIPLES

The Sub-Bottom Imager™ (SBI) uses multi-aspect acoustic intensity imaging to delineate sub-seabed stratigraphy and buried objects. These buried objects can be infrastructure such as cables and pipelines or can be geohazards such as boulders, hard-ground, man-made debris, abandoned seabed infrastructure and unexploded ordnance. SBI surveys reduce risk and offers subsequent cost reductions during the installation and burial of offshore infrastructure such as pipelines, power cables and umbilicals.

The SBI is an ROV/Vessel deployed unit with a 3.8m folding boom containing sonar projectors and receivers and associated electronics in bottles (Figure 1). The SBI utilizes high frequency (HF) chirp projectors to deliver a continuous 5m x 5m swath below the sub-seabed in real time (Figure 3). The high-resolution volumetric images provide 3D imaging of offshore infrastructure and geohazards to penetration depths of 5m or more depending on soil complexity (Figure 3).

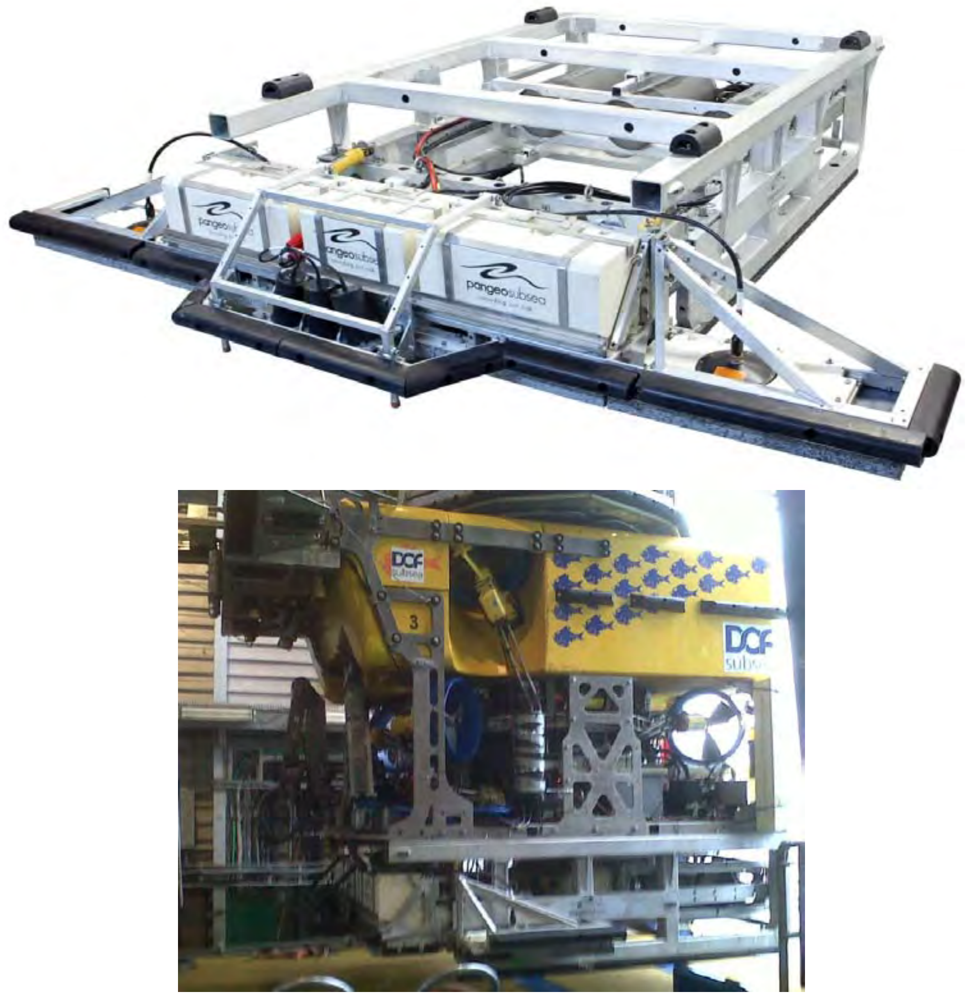


Figure 1: Sub-Bottom Imager™ (complete SBI equipment on an ROV skid (top panel) and SBI on a WROV bottom skid with multibeam also onboard (bottom panel)

3.1 Volumetric Imaging

During acquisition, the Sub-Bottom Imager™ repetitively ensonifies the volume of seabed under the hydrophone array and continuously receives the resulting acoustic reflections from within the seabed, as the array moves forward on the platform. This “raw” sonar data is digitized and transmitted via Ethernet over the vehicles fibre optic umbilical to the surface support vessel.

The high-volume, continuous flow of data is “rendered” on board by computers employing parallel processing architectures to produce a 3D volumetric data set of the seabed (Figure 3). The acoustic data is processed using a combination of beam forming algorithms and synthetic aperture algorithms to render a 3D data volume representing the acoustic reflectivity of the sub-bottom (Figure 2). The seabed under the array can be thought of as a three dimensional cube, encompassing an array of voxels, each comprising x, y, z position, signal intensity, and contribution count. The data is referenced to INS position and each cell contains the average signal intensity of the number of times that voxel was contributed to as the array traversed over top.

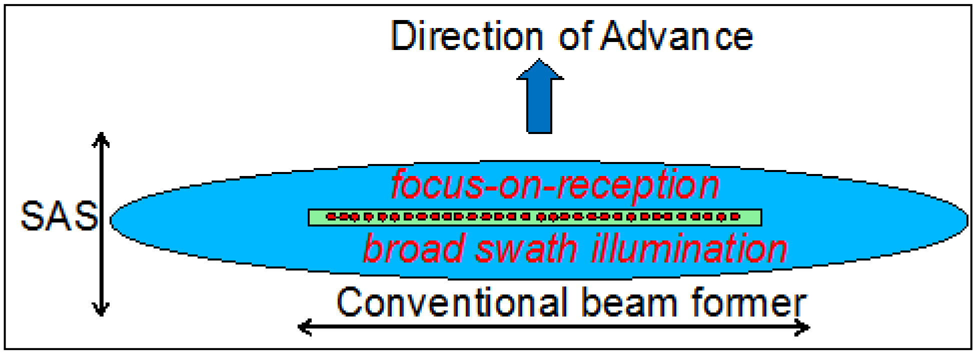


Figure 2: Schematic of SBI Method of Operation

Figure 3 shows the ensonified seabed volume after rendering limits are applied, visualized in the 3D survey software environment (in this case NaviModel). Signal intensity is represented by color with blue representing quieter areas and red higher intensity reflections. The upper blue layer is the water column below the transducer array with the adjacent red layer the seabed interface. The acoustic beam spreads out as the signal penetrates into the seabed, giving a volume width of 3.5m at the transducer, increasing to approximately 5m at the lower extent of the vertical penetration into the seabed of about 5m. The SBI rendered image is used to identify acoustic stratigraphy and acoustic anomalies, consistent with buried objects and geohazards, with a depth-dependent spatial resolution that is a function of the type of seabed (Figure 4).

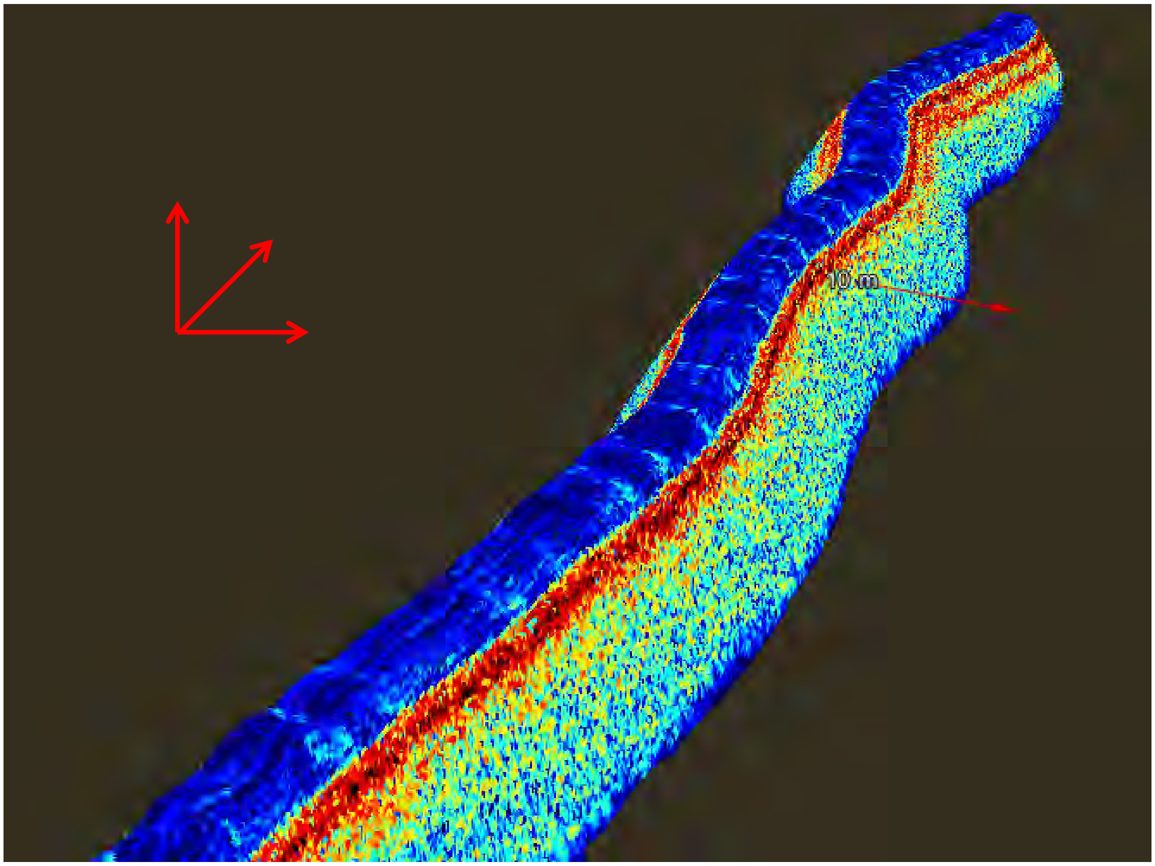


Figure 3: SBI rendered data volume along ROV flight path. This data volume is sectioned and sliced to reveal details of stratigraphy and buried.

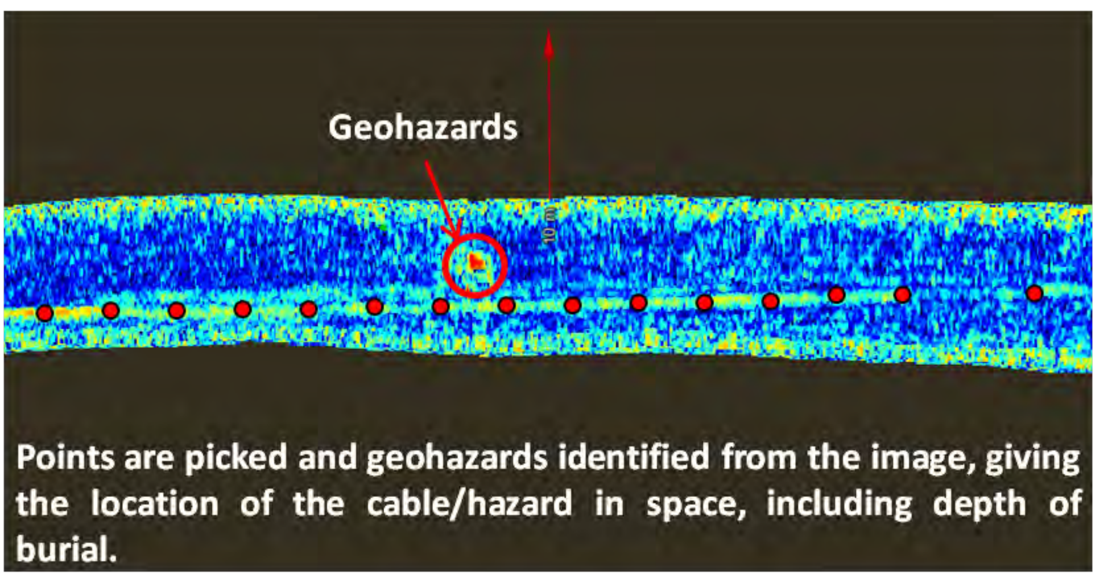


Figure 4: The SBI rendered image is used to provide x-y-z position of surveyed infrastructure and identified geohazards

4 RECEIVED SOUND LEVEL ANALYSIS

4.1 Acoustic Metrics

Sound pressure levels metrics are used to evaluate the levels of the Sub-Bottom Imager HF chirp sound sources and their effects on marine life. The acoustic metrics used are:

- rms sound pressure level (SPL, dB re 1µPa) in a stated frequency band over a time window of T seconds and containing the pulse is defined as:

$$SPL = 10\log_{10}\left(\frac{1}{Tp_0^2}\int_T \; p^2\,(t)dt\right) \qquad (1)$$

- sound exposure level (SEL, dB re 1µPa^2.s) is the time integral of the squared pressure in a stated frequency band over a stated time interval or event. In this case SEL_{sweep} represents 100% of the acoustic energy inone sweep:

$$SEL = 10\log_{10}\left(\frac{1}{T_0p_0^2}\int_T \; p^2\,(t)dt\right) \qquad (2)$$

  where T_0 is a reference time interval of 1 s and T is the duration of the transmitted signal and in marine settings the reference sound pressure, p_0, equals 1 µPa.

  The SPL and SEL are related by the following expression (where $T_0 = 1s$), which depends only on the duration of the time window T:

$$SEL = SPL + \; 10\log_{10}(T) \qquad (3)$$

- cumulative sound exposure level ($cSEL$, dB re 1µPa^2.s) represents the total energy received over a defined operational period (in this case 24 hours). For the Acoustic Corer™ case:

$$cSEL = \; SPL + \; 10\log_{10}(T_{sweep}) + \; 10\log_{10}(N_{sweep}) \qquad (4)$$

  where N_{sweep} is the number of sweeps transmitted in 24 hours.

The distances to isopleths of 180 and 160 dB re 1µPa for SPL and180 and 160 dB re 1µPa^2.s for SEL, as well as 198 and 186 dB re 1µPa^2.s for $cSEL$ are shown respectively in Table 2, Table 4, and Table 5 and are calculated as recommended in Southall et al. (2007), NMFS (2005) and MMPA (2007). In order to calculate the above levels the following transmission loss (TL) models are used:

- up to a distance of 3.5m a spherical spreading loss is assumed,

$$TL_{spherical} = 20\;\log_{10} R \qquad (5)$$

- at distances greater than 3.5m is estimated assuming cylindrical spreading loss:

$$TL_{cylindrical} = 10\;\log_{10} R \qquad (6)$$

IMPORTANT: It is crucial to recognize that this model represents the worse case scenario. That is, the transmission loss model is a substantial under-estimate of actual transmission losses as:

- directivity of the transmit signal is not taken into account and the values used are those of the rms pressure on the peak of the main lobe,

- transmission into sediments and absorption are not taken into consideration,
- the main lobe of the transducer points orthogonally to the seafloor and therefore substantial amount of the transmitted energy of the main lobe is transmitted into the subsurface
- in most applications of the SBI the water depth is greater than 20 metres and therefore the cylindrical transmission loss model beyond the 3.5 metre radius is substantially under-estimating the actual transmission loss.

Hence, the distance to the SPL_{iso} isopleth, $R(SPL_{iso})$, is calculated as in [5]:

$$R(SPL_{iso}) = \begin{cases} 10^{\frac{SPL(1) - SPL_{iso}}{20}} if SPL(1) \geq \ SPL_{iso} \ \geq SPL(3.5) \\ 10^{\frac{SPL(3.5) - SPLiso + 10 \log_{10}(3.5)}{10}} if SPL_{iso} \ \leq \ SPL(3.5) \end{cases} \qquad (7)$$

Where $SPL(x)$ the rms sound pressure level at x meters away from the transmitter (note that by definition $SPL(1) = SPL$) and,

$$SPL(3.5) = \ SPL(1) - 20 \log_{10}(3.5)$$

The distance to the SEL_{iso} isopleths is calculated as in [5]:

$$R(SEL_{iso}) = \begin{cases} 10^{\frac{SEL(1) - SEL_{iso}}{20}} if SEL(1) \geq \ SEL_{iso} \ \geq SEL(3.5) \\ 10^{\frac{SEL(3.5) - SEL_{iso} + 10 \log_{10}(3.5)}{10}} if SEL_{iso} \ \leq \ SEL(3.5) \end{cases} \qquad (8)$$

Where $SEL(x)$ the rms sound pressure level at x meters away from the transmitter (note that by definition $SEL(1) = SEL$) and,

$$SEL(3.5) = \ SEL(1) - 20 \log_{10}(3.5)$$

For the purpose of these calculations the source is considered stationary, which provides a substantial over-estimate of distances to sound level isopleths. The sound pressure levels of the cumulative sound pressure level, $cSEL$, are calculated as in the case of SEL, however all instances of SEL in Equation (8) are replaced with $cSEL$.

5 SOUND SOURCE INFORMATION AND CALCULATIONS

5.1 Volumetric Data Acquisition (HF Chirp Transducers)

5.1.1 High Frequency Chirp Transducer Background Information

The SBI is equipped with a Neptune 4108 C/D transducer as its HF chirp source. The transducer is generally operated in the 4.5 to 12.5 kHz frequency band. The continuous wave (CW) source level associated with these frequencies is shown in Table 1and Figure 5. From this figure the continuous sweep source level ($SL_{p\text{-}continuous}$) is determined to be 190 dB re 1µPa•m. In Table 1, the CW source level were determined using a calibrated S-range transducer and a calibrated hydrophone to illustrate the Neptune 4108 A/B transmit voltage sensitivities at each tested frequency.

Table 1: HF transducer continuous wave source level with frequency

Frequency (Hz)	CW Source Level (dB re: 1µPa·m)
4000	179.7
4500	180.0
5000	191.6
5500	189.8
6000	191.4
6500	189.0
7000	188.3
7500	189.4
8000	189.3
8500	187.3
9000	186.5
9500	186.7
10000	185.9
10500	186.1
11000	185.7
11500	187.1
12000	187.0
12500	187.9
13000	188.8
13500	184.9
14000	181.8

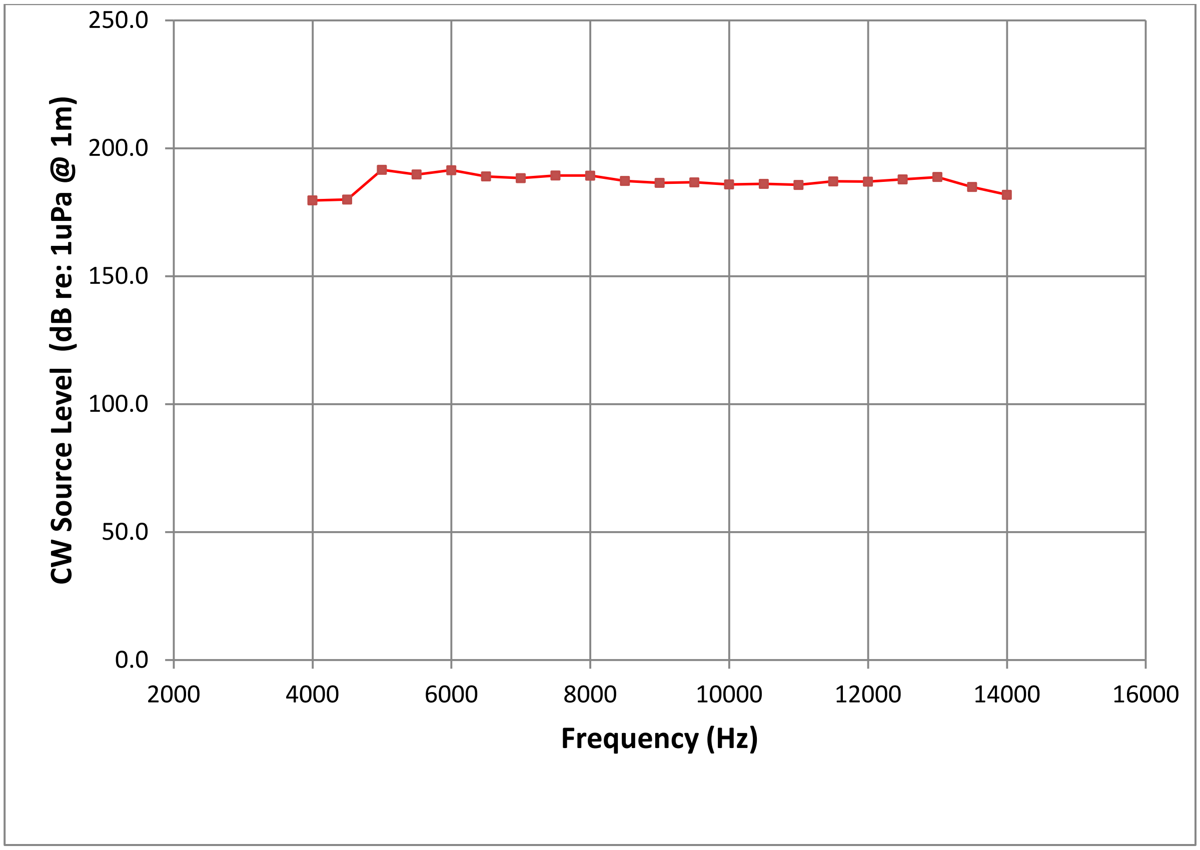


Figure 5: High Frequency transducer continuous wave sound level versus frequency

5.1.2 HF Chirp Transducer Acoustic Metrics

For a continuous SBI sweep:

$SL_{p\text{-}continuous}$= 190 dB re 1μPa•m

where at 1m from the source,

$$SPL_{chirplet} = SL_{p-continuous}$$

Therefore, for a sweep with a triangular wave-shape modulation:

$$SPL = SPL_{sweep} + 20 \log_{10} M$$

where,

M = triangular wave-shape modulation and rms to peak factor = $\sqrt{{}^{2}/_{3}}$

Provided that the SPL values are relatively flat across the total sweep bandwidth (as shown in Figure 5), the SPL value for the entire sweep is calculated as:

$$SPL = 190 - 1.8 = 188.2 \text{ dB re } 1\mu\text{Pa @1m}$$

and the sound exposure level associated with a single sweep is:

$$SEL = SPL + 10 \log_{10} T_{sweep}$$

where T_{sweep} is the total time between start of the sweep to the beginning of the next sweep,

$$T_{sweep} = 0.0769 \text{ sec}$$

which results in,

$$SEL = 188.2 + 10 \log_{10}(0.0769) = 177.1 \text{ dB re } 1\mu\text{Pa}^2\text{.s @ 1m}$$

The cumulative SEL ($cSEL$) is calculated by adding the SEL values (in dB scale) from all the sweeps received in 1 hour given a ping rate of 7 Hz. The calculation also assumes the worst-case scenario that the receiver does not move away from the source as the source moves in the water column:

$$cSEL = SEL + 10 \log_{10}(N_{sweep})$$

where N_{sweep} (= 25200) is the total number of sweeps received in 1 hour resulting in,

$$cSEL = 177.1 + 10 \log_{10}(25200) = 221.1 \text{ dB re } 1\mu\text{Pa}^2\text{.s @ 1m}$$

The distance to the SPL_{iso} isopleths is calculated using Equation 7 and the distances to the SEL_{iso} and $cSEL_{iso}$ isopleths is calculated using Equation 8.

The results of the isopleth calculations are shown in the table below**.**

Table 2: Source levels and maximally over-estimated distance to sound level isopleths for the high frequency (HF) chirp source

Source	SPL dB re: 1µPa	SEL dB re: 1µPa^2.s	Range (m) to $\boldsymbol{SPL_{iso}}$		Range (m) to $\boldsymbol{SEL_{iso}}$		Range (m) to $\boldsymbol{cSEL_{iso}}$	
			180 dB re: 1µPa	160 dB re: 1µPa	180 dB re: 1µPa^2.s	160 dB re: 1µPa^2.s	198 dB re: 1µPa^2.s	186 dB re: 1µPa^2.s
SBI HF Chirp	188.2	177.1	2.6	188.8	N/A	14.7	58.3	924.6

6 CONCLUSION

The results of sound level analysis are summarized in Table 3 and Table 4. The distances to *SPL* isopleths of 180 and 160 dB re1μPa, LF and HF Chirp *SEL* isopleths of 180 and 160 dB re: 1μPa^2.s, as well as LF and HF Chirp *cSEL* isopleths of 198 and 186 dB re: 1μPa^2.s are calculated as recommended Southall et al. (2007), NMFS (2005), MMPA (2007).

The calculation assumes the worst-case scenario and does not take into account the directivity of the transmit signal. There are risks associated with acoustic sounding where mammals may be present, but these are minimal due to the SBI operating height of 3.5m above the seafloor. This risk can be reduced further by implementing mitigation procedures that would involve beginning the survey, as part of set-up procedures, using low acoustic power settings and gradually increasing to full power levels to carry out the survey proper. By so doing, marine mammals within the vicinity of the survey area are made aware of the survey activity without harm and can move away from the area prior to the commencement of the survey using full acoustic power.

Table 3: Mean Received Levels at RUNES

Transducer (Frequency)	Pulse Width	Mean Received Level	Variance	Signal-to-Noise Ratio
HF Chirp (4.5 kHz – 12.5 kHz)	4.5 ms	134 dB	12	49 dB

Table 4: Summary of sound level results

Source	*SPL* dB re: 1μPa	*SEL* dB re: 1μPa^2.s	Range (m) $SPL_{isopleth}$		Range (m) to$SEL_{isopleth}$		Range (m) toc$SEL_{isopleth}$	
			180 dB re: 1μPa	160 dB re: 1μPa	180 dB re: 1μPa^2.s	160 dB re: 1μPa^2.s	198 dB re: 1μPa^2.s	186 dB re: 1μPa^2.s
SBI HF Chirp	188.2	177.1	2.6	188.8	N/A	14.7	58.3	924.6

7 REFERENCES

[1] B.L. Southall, AE.. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack, 2007. Marine Mammal Noise Exposure Criteria: Initial Recommendations. Aquatic Mammals, Volume 33, Number 4.

[2] Marine Mammal Protection Act (MMPA) amendment, 2007. Marine Mammal Commission with amendments by NOAA's National Marine Fisheries Service.

[3] National Marine Fisheries Service (NMFS), 2005. Assessment of acoustic exposures on marine mammals in conjunction with USS Shoup active sonar transmissions in Haro Strait, Washington, 5 May 2003.(NMFS Office of Protected Resources report).

[4] Analytical review of the Acoustic Corer™ sound source analysis report by PanGeo Subsea, 2013. Prepared for PanGeo Subsea by Jasco Applied Sciences.

Innomar Sub-bottom Profiler

SES-2000 medium-100

Parametric Sub-bottom Profiler

Performance

- water depth range: 2 – 2,000 m
- penetration: up to 70 m, depending on sediments
- layer resolution: up to 5 cm
- motion compensation: heave, roll
- beam width @ 3 dB: ±1° / footprint < 3.5 % of water depth for all frequencies

Transmitter

- primary frequencies: approx. 100 kHz (band 85 – 115 kHz)
- secondary low frequencies: 4, 5, 6, 8, 10, 12, 15 kHz (band 2 – 22 kHz)
- primary source level: > 247 dB//μPa re 1 m
- pulse width: 0.07 – 2 ms
- pulse rate: up to 40/s
- multi-ping mode
- pulse type: CW, Ricker, LFM (chirp)

Acquisition

- primary frequency (echo sounder, bottom track)
- secondary low frequency (sub-bottom data, multi-frequency mode)
- sample rate 96 kHz @ 24 bit

System Components

- transceiver unit 19 inch / 12 U (WHD: 0.52 m x 0.58 m x 0.40 m; 56 kg)
- transducer incl. 30 m cable (WHD: 0.50 m x 0.12 m x 0.50 m; 60 kg)
- system control: internal PC
- KVM remote control

Software

- SESWIN data acquisition software
- SES Convert SEG-Y/XTF data export
- SES NetView remote display
- ISE post-processing software

Power Supply Requirements

- 100 – 240 V AC / 50 – 60 Hz
- power consumption: < 700 W

Innomar

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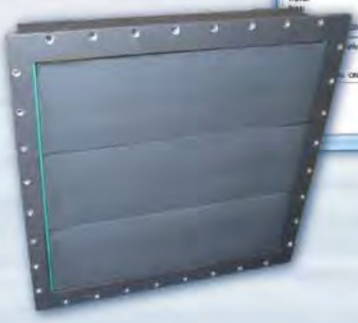
INNOMAR deep-36

Parametric Sub-bottom Profiler

Transducer



Screenshot of the operating software

Top-side unit

Performance

- water depth range: 5 – 6,000 m (option 10,000 m)
- penetration: up to 150 m, depending on sediments
- layer resolution: up to 12 cm
- motion compensation: heave, roll, pitch (option)
- beam width @ 3 dB: ± 1.5° / footprint < 5.5 % of water depth for all frequencies

Transmitter

- primary frequencies: approx. 36 kHz (band 30 – 42 kHz)
- secondary low frequencies: 2, 3, 4, 5, 6, 7 kHz (band 1 – 10 kHz)
- primary source level: > 245 dB//µPa re 1 m
- pulse width: 0.15 – 5 ms
- pulse rate: up to 40/s
- multi-ping mode
- pulse type: CW, Ricker, LFM (chirp)

Acquisition

- primary frequency (echo sounder, bottom track)
- secondary low frequency (sub-bottom data, multi-frequency mode)
- sample rate 48 kHz @ 24 bit

System Components

- transceiver unit 19 inch / 16 U (WHD: 0.52 m x 0.74 m x 0.50 m; 95 kg)
- transducer with frame excl. cable (WHD: 0.90 m x 0.30 m x 0.90 m; 335 kg)
- system control: internal PC
- KVM remote control

Software

- SESWIN data acquisition software
- SES Convert SEG-Y/XTF data export
- SES NetView remote display
- ISE post-processing software

Power Supply Requirements

- 100 – 240 V AC / 50 – 60 Hz
- power consumption < 900 W

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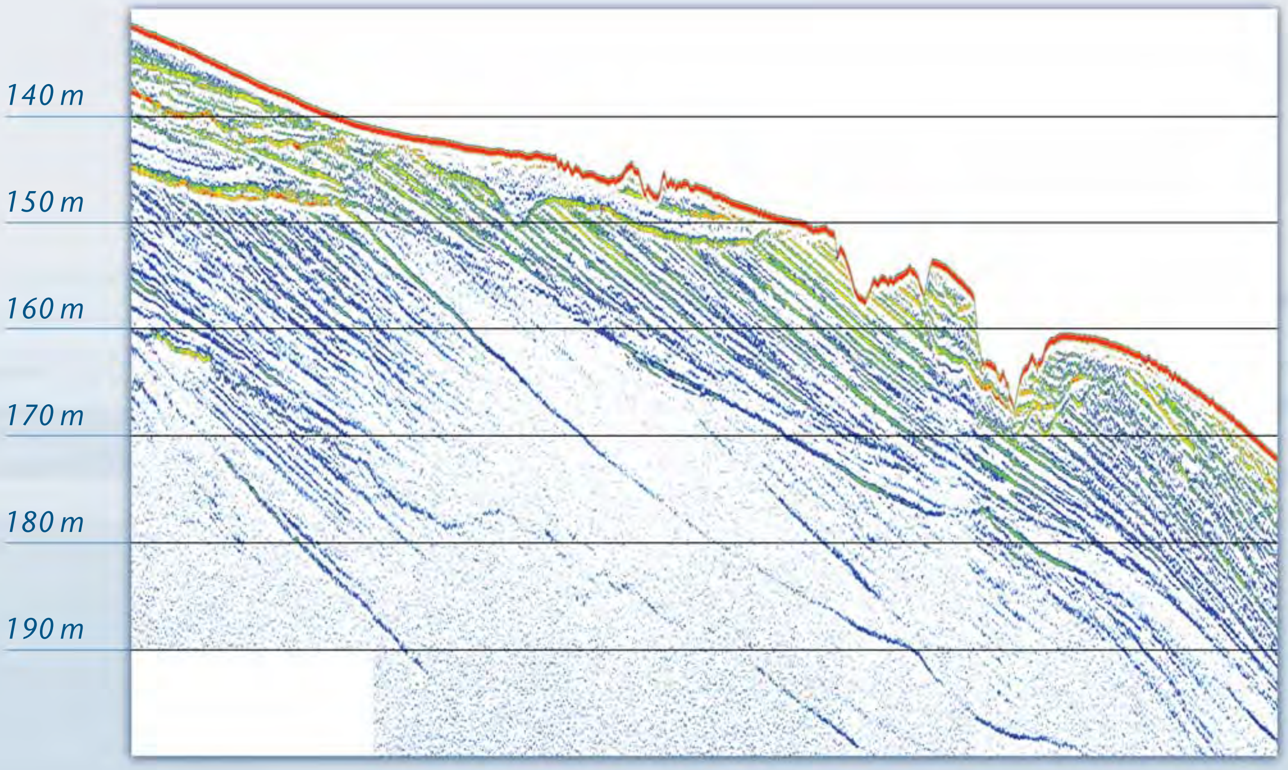
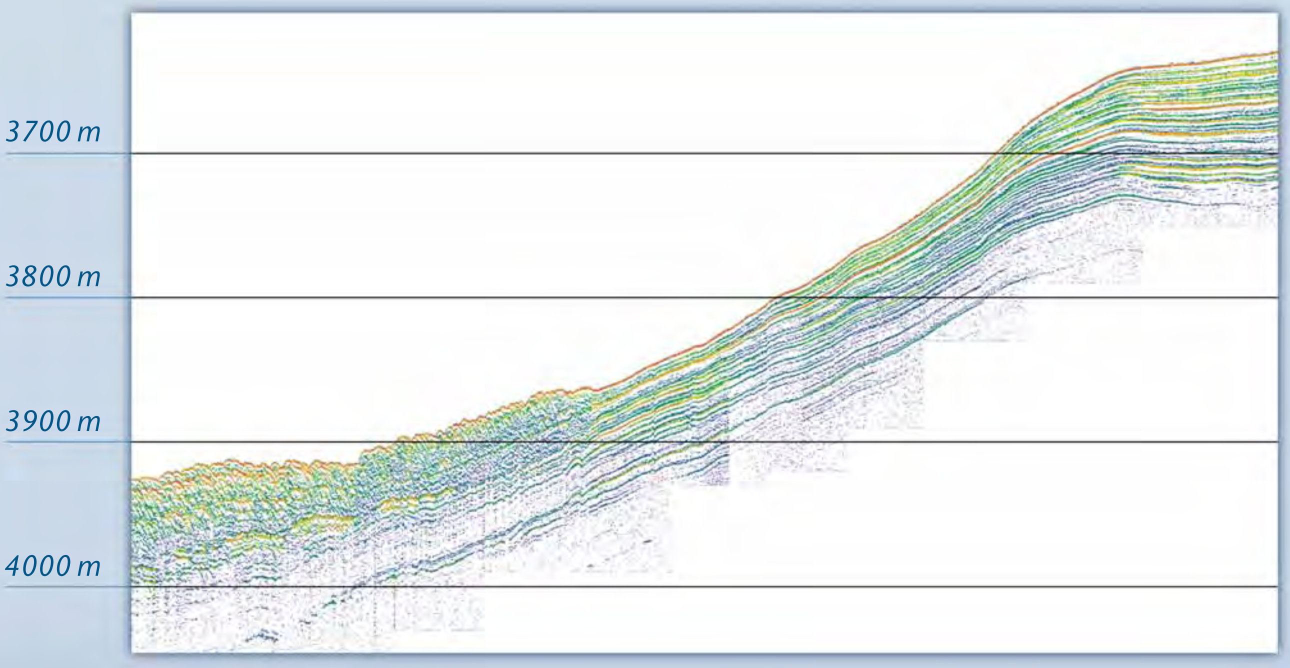
Survey examples of SES-2000 deep-36



South Korean Coast echo plot example
Frequency 4 kHz, pulse length 750 µs, profile length 11 km, survey speed 13 knots



***Atlantic Ocean (Argentina) echo plot example** – Frequency 4 kHz, pulse length 1500 µs, profile length 65 km*

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Appendix B

Distances to Acoustic Thresholds Corresponding to Level B Harassment for High Resolution Geophysical Sources

Source Name: SIG ELC 820 Sparker at 750J

INPUT VALUES (LEVEL B)	
Threshold Level	*160*
Source Level (dBrms)	*203*
Frequency (kH)	*0.01*
Beamwidth (degree)	*180*
Water depth (m)	*5*

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	8.8249E-07
TL coefficient	20
Slant distance of threshold (m)	**141**
Vertical depth of threshold (m)	8.6373E-15
Horizontal Threshold Range (m)	**141**

Source Name: Geo Marine Survey System 2D SUHRS at 400J

INPUT VALUES (LEVEL B)	
Threshold Level	*160*
Source Level (dBrms)	*195*
Frequency (kH)	*0.2*
Beamwidth (degree)	*180*
Water depth (m)	*5*

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	0.000352994
TL coefficient	20
Slant distance of threshold (m)	**56**
Vertical depth of threshold (m)	3.43042E-15
Horizontal Threshold Range (m)	**56**

Source Name: Edgetech 2000-DSS

INPUT VALUES (LEVEL B)	
Threshold Level	*160*
Source Level (dBrms)	*195*
Frequency (kH)	*2*
Beamwidth (degree)	*24*
Water depth (m)*	*5*

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	0.035275879
TL coefficient	20
Slant distance of threshold (m)	**56**
Vertical depth of threshold (m)	54.77626564
Horizontal Threshold Range (m)	**1.062782808**

Source Name: Edgetech 216

INPUT VALUES (LEVEL B)	
Threshold Level	*160*
Source Level (dBrms)	*179*
Frequency (kH)	*2*
Beamwidth (degree)	*24*
Water depth (m)*	*5*

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	0.035275879
TL coefficient	20
Slant distance of threshold (m)	**9**
Vertical depth of threshold (m)	8.803328407
Horizontal Threshold Range (m)	**1.062782808**

Source Name: Edgetech 424

INPUT VALUES (LEVEL B)	
Threshold Level	*160*
Source Level (dBrms)	*180*
Frequency (kH)	*4*
Beamwidth (degree)	*71*
Water depth (m)*	*10*

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	0.140819438
TL coefficient	20
Slant distance of threshold (m)	**10**
Vertical depth of threshold (m)	8.141155184
Horizontal Threshold Range (m)	**5.807029557**

Source Name: Edgetech 512i

INPUT VALUES (LEVEL B)	
Threshold Level	*160*
Source Level (dBrms)	*179*
Frequency (kH)	*0.7*
Beamwidth (degree)	*80*
Water depth (m)*	*10*

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	0.004323847
TL coefficient	20
Slant distance of threshold (m)	**9**
Vertical depth of threshold (m)	6.894399988
Horizontal Threshold Range (m)	**5.785088487**

Source Name: Pangeosubsea Sub-Bottom Imager™

INPUT VALUES (LEVEL B)	
Threshold Level	*160*
Source Level (dBrms)	*190*
Frequency (kH)	*4*
Beamwidth (degree)	*120*
Water depth (m)	*5*

COMPUTED VALUES (LEVEL B)	DO NOT CHANGE
alpha (dB/km)	0.140819438
TL coefficient	20
Slant distance of threshold (m)	**32**
Vertical depth of threshold (m)	16
Horizontal Threshold Range (m)	**8.660254038**