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V.E. Kostylev[1], G. King[2], D. Manning[1], P. Meslin[1], S. Graham[2] S. Nunn[2], D. Levy[2], and J. Fizzard[2]

[1]Geological Survey of Canada, 1 Challenger Drive, Dartmouth, Nova Scotia
[2]Canadian Hydrographic Service, 1 Challenger Drive, Dartmouth, Nova Scotia

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Publications in this series have not been edited; they are released as submitted by the author.

Table of contents

List of tables

Table of figures

BACKGROUND AND OBJECTIVES

A new Marine Geoscience for Marine Spatial Planning Program (MGMSP) lead by Natural Resources Canada (NRCan) provides innovative regional geoscience products to support the Department of Fisheries and Oceans (DFO) Marine Spatial Planning and evidence-based decision-making. The Newfoundland and Labrador bioregion has large gaps in geological and geophysical data coverage, and the area immediately North of Orphan basin (from Orphan Spur to Notre Dame Trough) is particularly data poor. At the same time this area is known as the NE Newfoundland fishery closure, where there is a need in regulating fishing and hydrocarbon exploration activities for the purpose of resolving seabed use conflicts.

The objective of the CCGS Louis S. St. Laurent 2019 expedition was to carry out an acoustic survey of seabed along the Northeast Newfoundland shelf and slope in order to collect high-quality bathymetric and sub-surface reflection data, using a multibeam echosounder and subbottom profiler. This information is critical for understanding the seabed geomorphology, geological hazards, as well as benthic habitats in the region.

The survey covered a significant part of DFO's NE Newfoundland fishery closure (Figure 1), as well as an ecologically and biologically significant areas known for high-density populations of deep-sea corals, sponges and sea pens.

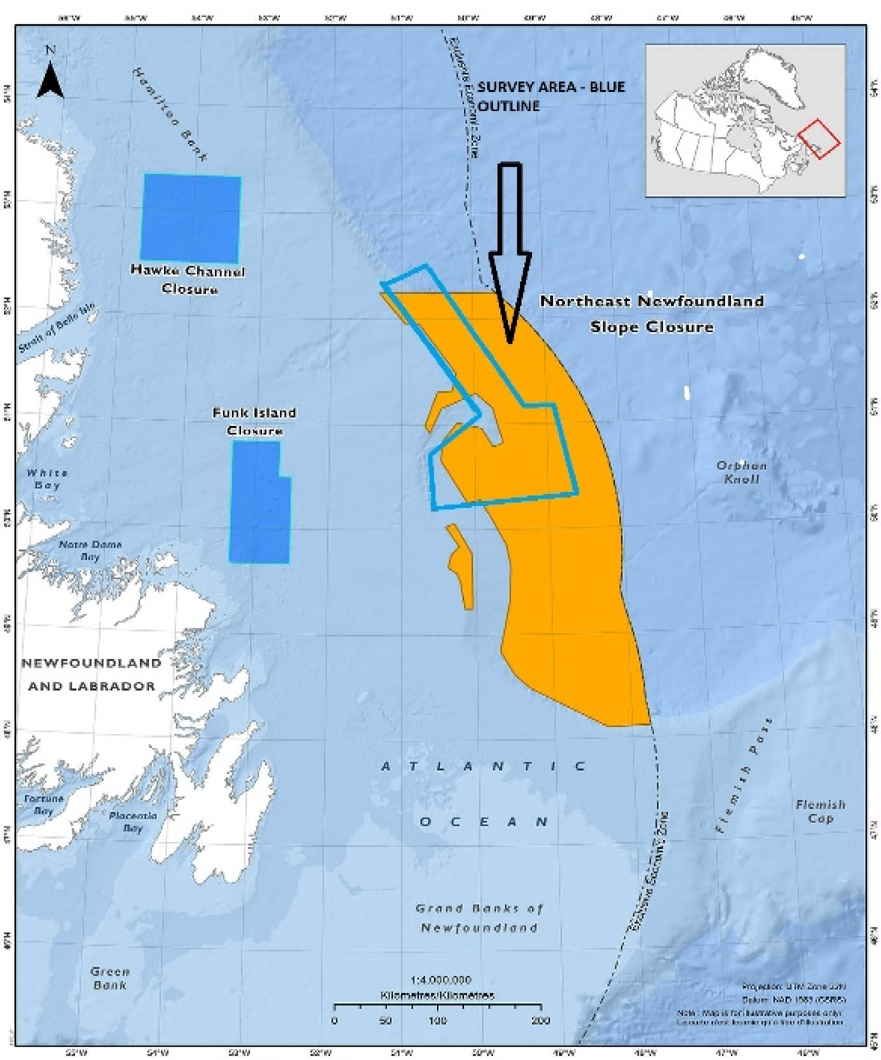

Figure 1. Outline of the planned survey (blue polygon) in relation to the NE Newfoundland fishery closure (orange polygons).

PARTICIPANTS

LSSL 2019 was a joint research vessel expedition between the Geological Survey of Canada and Canadian Hydrographic Service (Figure 2). The total of ten participants led different operations on board the ship (Table 1).

Table 1. Participants of the CCGS LSSL 2019 expedition.

First Name	Last Name	Affiliation	Role
Vladimir	Kostylev	GSC-A	Chief Scientist
Desmond	Manning	GSC-A	Technical officer
Patrick	Meslin	GSC-A	Technical officer
Glen	King	CHS	Hydrographer-In-Charge
Steve	Nunn	CHS	Hydrographer
Sarah	Graham	CHS	Hydrographer
Justin	Fizzard	CHS	Hydrographer
David	Levy	CHS	Technical officer

Figure 2. Participants of the LSSL 2019 expedition. Left to right: David Levy, Justin Fizzard, Sarah Graham, Desmond Manning, Stephen Nunn, Glen King, Patrick Meslin, Vladimir Kostylev. Photograph by V. Kostylev NRCAN photo 2021-502.

SUMMARY OF ACTIVITIES

In August 2019 a joint Geological Survey of Canada (Atlantic) and Canadian Hydrographic Service team carried out multibeam mapping and subbottom profiling on board the Canadian Coast Guard Ship *Louis S. St. Laurent* (LSSL) in the northern part of Orphan Basin, as well as along the shelf break and slope from Orphan Spur to Notre Dame Trough. The LSSL departed St. John's on the 3rd of August and the GSC crew disembarked in St. Anthony NL on the 15th of August at the end of the survey. Mobilisation of the gear took place in St John's, which required additional travel in advance of the cruise. The cruise started 2 days later than expected because of coastguard crew certification and health issues. The cruise terminated earlier than planned because of health and safety issues (a coastguard crew member had been deployed to hospital in St. Anthony's).

The cruise involved collection of Multibeam Echosounder (MBES) data using a Kongsberg EM 122 and sub-bottom profiler data using a Knudsen 3.5 kHz sub-bottom profiler. CHS personnel conducted MBES data collection in the area of interest while GSC personnel carried acquisition of sub-bottom profiler data.

The Hydrographic survey was carried out in compliance with the *CHS Standards for Hydrographic Surveys* and the *Hydrographic Survey Management Guidelines*. This includes meeting *International Hydrographic Office Order 1b* for MBES data in controlled areas. Appropriate reference, administration and safety manuals, relevant marine regulations and departmental policies and procedures were adhered to.

NRCan had not collected sub-bottom data on board the CCGS Louis St. Laurent since the close of the 2016 UNCLOS program season. CHS did collect some data in 2018 at the request of NRCan, however reported issues of interference with the MBES aboard the vessel resulted in the shutdown of the Knudsen sub-bottom system. On the second leg of the 2018 CHS LSSL program there was another attempt to collect sub-bottom data. This time the Knudsen server failed and was removed from the Louis to be returned to NRCan for repair. To prevent these problems from occurring on the 2019 cruise, the mobilisation dates for LSSL 2019 expedition were made concurrent with the CHS dates from July 22nd to July 24th 2019 inclusive. This time was used to ensure that there would be no interference with the Kongsberg EM 122 Multibeam Echo sounder, as well as checking that the sync/trigger from the sounder was working, and that no other equipment issues persisted.

A daily log of events is shown in Appendix A.

EQUIPMENT AND PROCEDURES

4.1 Mobilisation of GSC gear

The equipment was sent to the CCGS Louis St. Laurent ahead of time. It filled one tri-wall plus the space DFO could spare in their tri-walls. DFO facilitated the shipment of all equipment to South Base in St. John's, where it was held until our arrival on the 22nd of August 2019. It was late afternoon on the 22nd of August before the equipment was accessible to us. All tri-walls were dropped into the forward hold, two floors below the forward lab.

Once on board we found that the LSSL has a new three channel Knudsen 3260 chirp system. The third channel was for a 200 kHz transducer. This left us the possibility either to use this as a primary system in the future, or to use our own system with LSSL system as a spare. More information on the configuration of the LSSL system is required.

The 12 kHz and 3.5 kHz transducer cables were removed from LSSL sounder to be used for our 3260 chirp system, which was still in place from 2016. We never used the 12 kHz channel but connected it anyway in case it was needed. Access to the back of the equipment rack was limited. The back of the rack is also very busy with cables, so the chance of unwittingly pulling something out was significant.

We tested the impedance of the transducers over a band of frequencies using the Knudsen Echosim kit. This not only confirmed which cable was connected to which transducer, but also the apparent resonant frequency for each. Appendix B contains the impedance values of the 3.5 kHz array and the 12 kHz over a range of frequencies.

Two serial cables and the trigger/sync cables between the Applanix POS MV System and the Knudsen were still in place from 2016. Working space is an issue on the LSSL so we used the rack mount monitor that was already in place and connected to the ship's 3260 chirp system. For the same reason of limited space we decided to run Regulus, NavNet, and digital logging software on one Regulus machine.

Comm ports 1 and 2 on the Knudsen server did not appear to be working properly during our setup. Comm ports 3 through 6 had no issues and were used. The problem, discovered later in the trip, turned out to be a small mix up during the installation of the motherboard. The ports were mistakenly switched at that time.

Patrick Meslin had recorded the port settings from 2016 LSSL expedition and had the file with him. Although all baud rates from 2016 were 4800, CHS chose to run at 19200, so our rates were swapped to match. Port settings for the Knudsen server were as shown in Table 2.

Table 2. Port settings for the Knudsen server along with transmitted National Marine Electronics Association (NMEA) strings.

Comm 3	19200	input	TSS1 (Heave Comp.)
Comm 4	19220	input	CPGGA from POS
Comm 5	4800	output	DBT to Ship's Network
Comm 6	4800	output	DBT to Navnet

The clock on the Regulus computer had drifted approximately ten minutes while in storage for the month preceding the trip. We used a free trial version of a time sync software called NMEAtime from VisualGPS that syncs the computer time using a seral GPS string (https://www.visualgps.net). We were not syncing to any other equipment, so we did not really need a time server.

The navigation feed from the POS MV was split between the Knudsen server and the Regulus computer. We made up a Y-cable and split the navigation feed a second time at the Regulus machine. The split navigation and the DBT feed from the Knudsen were brought into the Regulus machine using a 4 port Edgeport serial to USB converter. Port settings for the Regulus computer were the following (Table 1Table 3):

Table 3. Port settings for the Regulus computer

Comm 11	19200	input	GPS from POS MV
Comm 12	19200	input	HDG from POS
Comm 13	4800	input	DBT from POS

The Chief Scientist's GIS workstation was set up on the far starboard side of the lab and patched in to the science network for easy access to files from the Knudsen.

The POS MV calculates heave compensation for only two different offsets. It was unclear whether both were being used so we could not have changed those values without, perhaps causing issues. Also, we did not really know the offsets for our sea chest. We connected the second cable to, at least, have access to the uncertain, or approximate compensation values. The heave compensation we output to the Knudsen had offsets of zero on all axes. We assumed this to be the course over ground (COG).

Once the mobilisation was complete the MBES was run simultaneously with the Knudsen for a time alongside the pier. The sync from CHS worked well. We limited our ping rate to one second as we were in shallow water. No interference was observed. The system tested well and there were no outstanding issues.

4.2 Knudsen 3260 Echo-Sounder

3.5 kHz sub bottom profiler data collection started immediately upon leaving St. John's harbour using the Knudsen sounder and server installed on board LSSL (Figure 3). Transducer test results are shown in Appendix B. SegY, KEB, and KEA formats were logged using Sounder Suite Echo Control Client 4.09. Sub-bottom data was collected all the way to the work site using a 100 m window range. A return to St. John's and back gave us three runs of data over that route at approximately 16 knots. The data was remarkably good for that speed because the weather was unusually favourable.

We initially ran outside St. John's harbour with heave compensation turned off to get a baseline notion of the vessel's movement. Running with heave compensation applied did show some improvement so we continued to survey using the compensation from the POS. The weather on site was so good that it is hard to estimate the real effect of applying heave compensation without the correct offsets.

Figure 3. Knudsen 3.5 kHz sub bottom profiler server. Photograph by V. Kostylev NRCAN photo 2021-503.

The resulting late start led to the decision to collect data at as high of a speed as could be managed (10 – 12 knots). Again, the quality of the data was very good. The range window was opened to 200 meters in the region of the canyons. The MBES choked for several short periods over the course of work in the area. During this time, we swapped back to internal triggering.

A negative side-effect of syncing with the MBES as master is that in deep water we could not have multiple shots in the water column. At times our ping period was over seven seconds. This could not be avoided and lead to lower resolution data sets.

When collecting SegY data we broke file (stopped logging, made a required change, started logging) whenever a change had to be made to the transmit power, the gain, or the range window. Overuse of changes in these settings should be avoided as much as is reasonable.

On very few occasions, the bottom was lost, momentarily, but quickly regained. This is a primary advantage of having the system supervised. In automatic mode the software increases the range of the phase window and gain until bottom is recovered fowling the SegY file. It does not reduce the window automatically once it is tracking bottom again. As mentioned, changes in the phase range window and gain while collecting SegY data should be avoided. The automatic settings are fine if one is using the system purely as a sounder, but not to collect sub-bottom data in a region with rapid changes in depth. Overall, the equipment worked well.

Assuming we leave the present Knudsen sounder on board the CCGS Louis S. St. Laurent, we will not need to take a spare next time since the ship already has one. However, we need to find out more about the power distribution and the configuration of the installed Knudsen system.

The spares and mobilised supplies proved to be complete. We had the tools (fairly minimal) and equipment needed to cover off our own equipment and build whatever connections we required.

The communication port mix-up was a minor problem, given we had six ports to choose from. In the future missions we should check for little glitches like that before we send equipment into the field. The problem was discovered early on, and we had two computers with us that could have been used as spares.

For the purpose of clock synchronisation, a time server may be an overkill for 3.5 kHz data collection on the LSSL. Absolute time accuracy was not critical for this mission, and an affordable software application (WHICH) proved to be adequate. There was not much space for another cable to pass through the acquisition room bulkhead for the GPS antenna, but it could be done with some effort. More importantly, we need to visit options for the future as we will be running into a problem with our present server in three years.

The Regulus software worked well with all required charts available. Using the heave compensation with the COG offsets seemed to be beneficial, but given the unusually good weather, we might not have had a good test. We need to find out more, for example: What are the offsets to our transducer array? How are these offsets entered into the POS MV? Given that there are two feeds in place, is anyone using the second one? Can we, in conjunction with CHS, change the offsets to be useful to us?

No interference of 3.5 kHz system with the Kongsberg EM 122 was observed over the course of the cruise. Thumbnails of the collected data segments are shown in Appendix D.

4.3 Kongsberg EM122 Multibeam Echosunder

Multibeam data acquisition was carried out by the CHS team on a 24-hour basis. Kongsberg Seafloor Information System (SIS) version 4.3.2 was used for the Kongsberg EM122 MBES (12 kHz full ocean depth capable) echo sounder data logging and Sound Velocity data file preparation. Applanix POSMV 320M V5 – Position and Orientation System was used with Applanix POSVIEW version 8.46 software installed on the multifunction computer in order to collect POSPAC log files. Global Mapper v13 with GPS NMEA input for route control and planning was also installed on the multifunction computer. A new HP z440 desktop with Windows 10 OS was enabled with HIPS v10.4.7 for data processing and Quality Control (QC) and Base Editor v4.4 for planning and data QC. The workstation layout and the diagram of EM122 system setup are shown below (Figure 4 and Figure 5). Location of IMU and GPS offsets are shown in Figure 6 and Figure 7 correspondingly.

Figure 4. LSSL EM122 Survey Lab Layout (MBES acquisition and processing). Photograph by V. Kostylev NRCAN photo 2021-504.

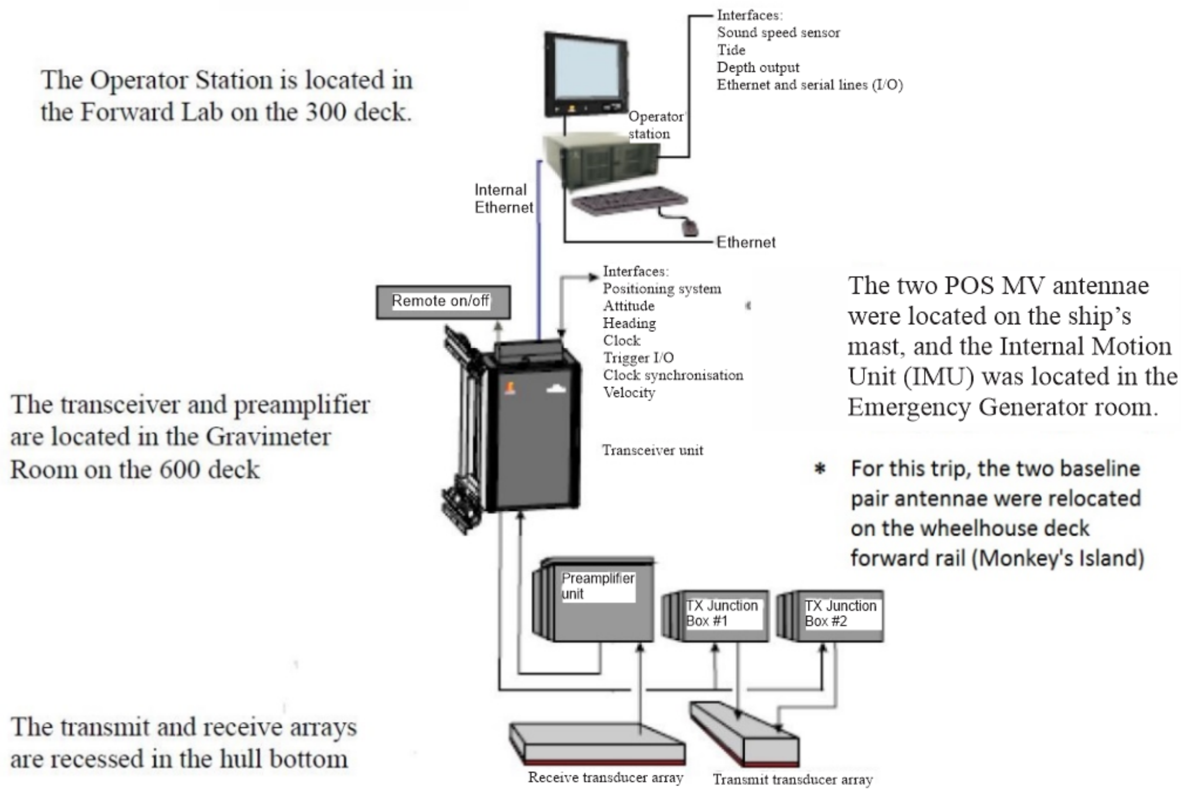

Figure 5. Diagram of LSSL EM122 System

System alignment value adjustments: Dimensional control values used during October 2018 were checked during the July 2019 mobilization. See Appendix 1 for POSMV settings and Appendix 2 for SIS settings. LSSL draft was recorded prior to departure on August 3 and at St. Anthony on August 15th. Appropriate waterline adjustment was entered in SIS on the same dates.

Horizontal datum: Fugro's Marinestar correction service was utilized for the entirety of this survey. Survey instructions for 2019 required datum ITRF(2008), epoch Jan 1, 2010. The ITRF 2014 corrections are equivalent to the required ITRF2008 datum. "Thus, ITRF2014, ITRF2008 and WGS84 (G1674) are likely to agree at the centimetre level, yielding conventional 0-transformation parameters." *Fugro Marinestar Support Portal Datum section (referenced Oct 2019)*.

Calibration adjustment: Targeted line acquisition was carried for calibration of the EM122. The calibration processing results of Pitch and Roll were both 0.00 (zero). Bad weather prevented a return to a seafloor area for specific Yaw line running. During post-processing, the data was re-visited for observation of suitable line pairings which would allow for Yaw calibration. The calibration resulted in a heading adjustment of -0.8 °. This was applied to the vessel configuration file in HIPS and SIPS, with all line data re-merged.

Data processing: Data processing was completed in accordance to the CHS Standards for Hydrographic Surveys and the Hydrographic Survey Management Guidelines. Caris HIPS and SIPS version 10.4.7 was used for MBES data processing on board ship. POS files were applied to all the MBES data as part of standard processing procedure. As most depth soundings collected in the Area of interest exceeded 400 m, zero tide was appropriate for preliminary evaluation and quality checking. All MBES data were processed within 48 hours of collection. Outlier removal and NAVWARN review occurred during preliminary QC using HIPS subset tool. There were no NAVWARN's issued for the areas surveyed August 2-15. During final quality checking and quality assurance GPS tides were applied with the model CANEAST2015v1_NAD83_CD. HIPS csar files and gridded bathymetry and backscatter surfaces were created with resolutions varying from 50 m for deep water to 20 m for shallower water. The quality of water column data was unknown to us at this time, though what was collected fit on one 2 TB external drive.

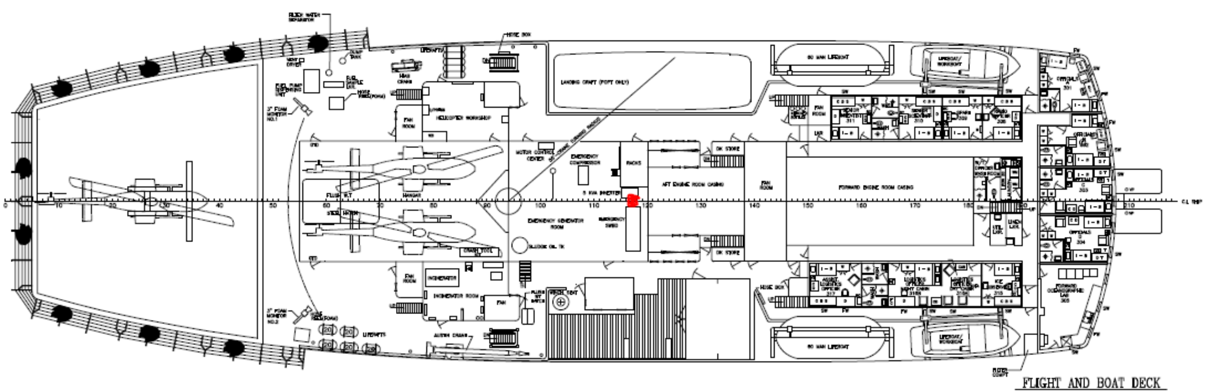

Figure 6. Location of IMU on the flight deck indicated with a red dot.

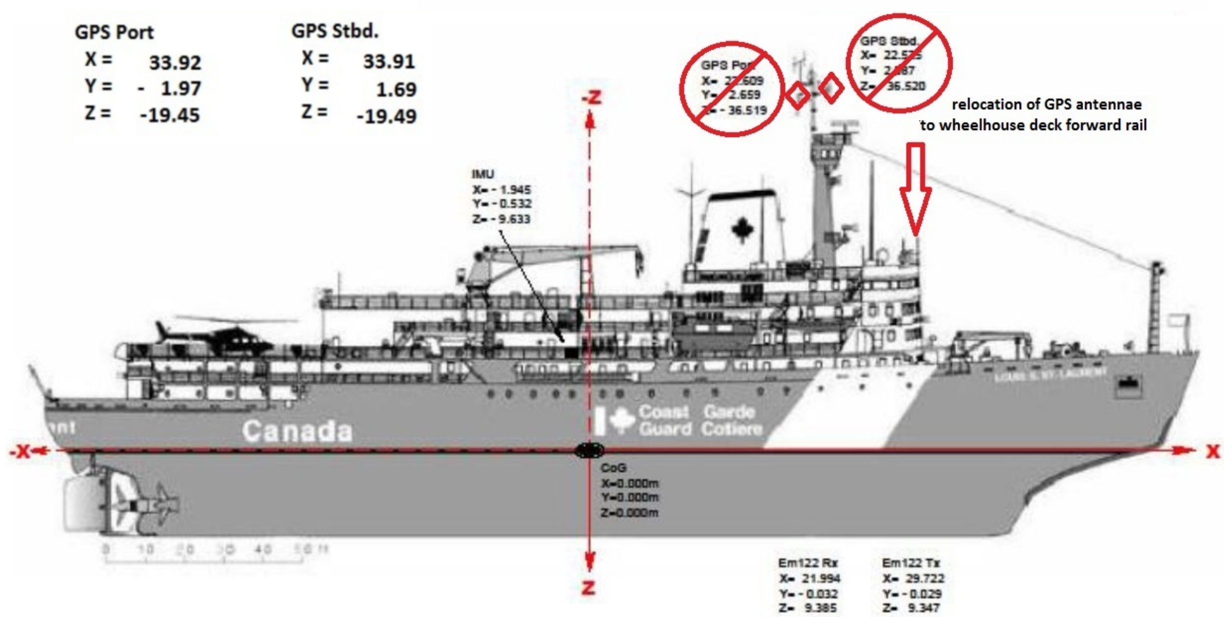

Figure 7. LSSL 2019 System coordinates, indicating new location of GPS antennae, as well as IMU, and MBES. The previous positions of GPS antennae are shown in crossed-out red circles.

4.4 Lockheed Martin MK21 – Expendable Sound Velocity System

Sound velocity was obtained for sound velocity corrections and processed using Lockheed Martin MK21 Oceanographic Data Acquisition System, mobilised on LSSL for the Joint Oceanographic Ice Survey program. The profiles were obtained one to several times a day to produce reasonable spatial coverage for the survey area. The MK21 USB system was run from a laptop PC computer operating in MS Windows. The operator used the computer keyboard and display to select the type of probe to be launched and other parameters to be stored with the data such as date, time and latitude/longitude. Geographic position was obtained automatically from the ship's navigation (NMEA 0813), and visually validated. The computer performed system diagnostics and prelaunch tests and then indicated that the probe was ready for launch. It received probe data during the probe descent and displayed and stored the vertical profiles data. Data was saved in an ASCII text format (.edf, .rdf) so the user can readily generate the measured profiles using spread sheet applications or transfer data to ray path or range prediction programs (e.g. Kongsberg SIS). Water property data was collected using XBT and XSV left over from UNCLOS cruises. XSV-02 are operational to a max water depth of 2000 m and up to 6 knots vessel speed. They were deployed using 3m-LA handhelds, with vessel slowing down to 5-6 knots. Two XSV drops had to be repeated over the course of the cruise because of malfunction. The XSVs have some added electronics components including a battery, so the use of the older units does pose a small risk.

Two people were required to go aft and deploy the XSV, while at least one person had to remain in the acquisition lab. For this reason, velocity casts were conducted in the daytime when more personnel were available. The summary of casts is shown below (Table 4). Plots of sound velocity profiles are shown in Appendix C.

Table 4. Summary of XSV deployments.

Probe Type	Terminal Depth	Depth Coeff. 1	Depth Coeff. 2	Depth Coeff. 3	Depth Coeff. 4	Date of Launch	Time of Launch	Latitude	Longitude
T-6	460 m	0	6.691	-0.00225	0	08/04/2019	14:08:21	50 50.77246N	49 55.55762W
XSV-02	2000 m	0	5.5895	-0.001476	0	08/05/2019	17:19:06	50 58.92871N	49 47.22852W
XSV-02	2000 m	0	5.5895	-0.001476	0	08/06/2019	09:43:06	51 37.05518N	50 22.50781W
XSV-02	2000 m	0	5.5895	-0.001476	0	08/06/2019	22:46:27	52 19.83691N	51 8.161130W
XSV-02	2000 m	0	5.5895	-0.001476	0	08/07/2019	11:44:19	51 31.74805N	50 9.592770W
XSV-02	2000 m	0	5.5895	-0.001476	0	08/07/2019	16:30:10	52 1.093750N	50 44.73242W
XSV-02	2000 m	0	5.5895	-0.001476	0	08/08/2019	10:59:28	51 43.14200N	50 17.87300W

PRELIMINARY RESULTS

As a result of this cruise, Canadian North Atlantic multibeam coverage was augmented by about 13,000 square kilometers of new bathymetric data and more than 2400 line miles of sub-bottom profiler data (Figure 8 and Figure 9).

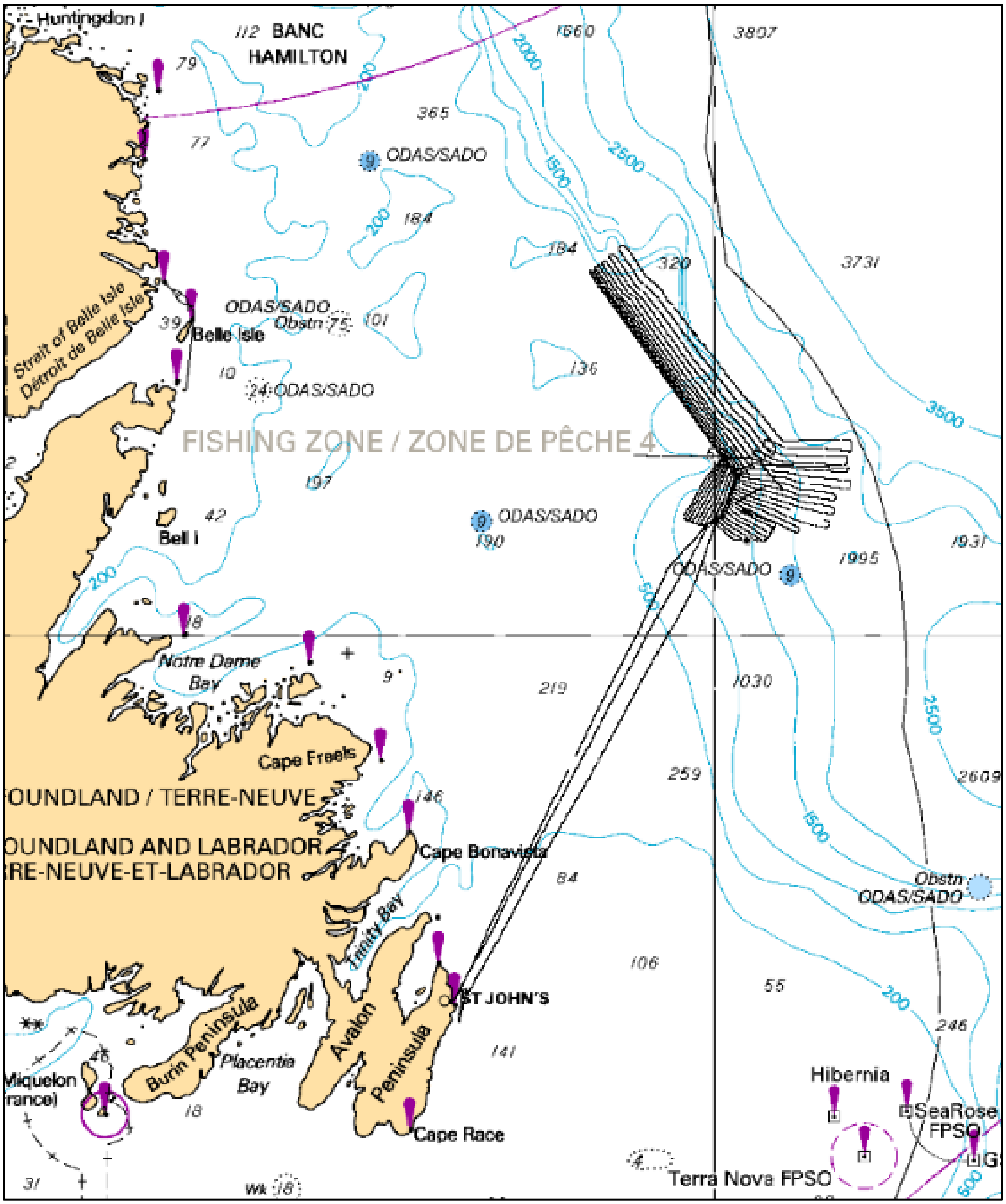

Figure 8. Ship tracks of the LSSL 2019 survey shown as black lines on top of navigation chart.

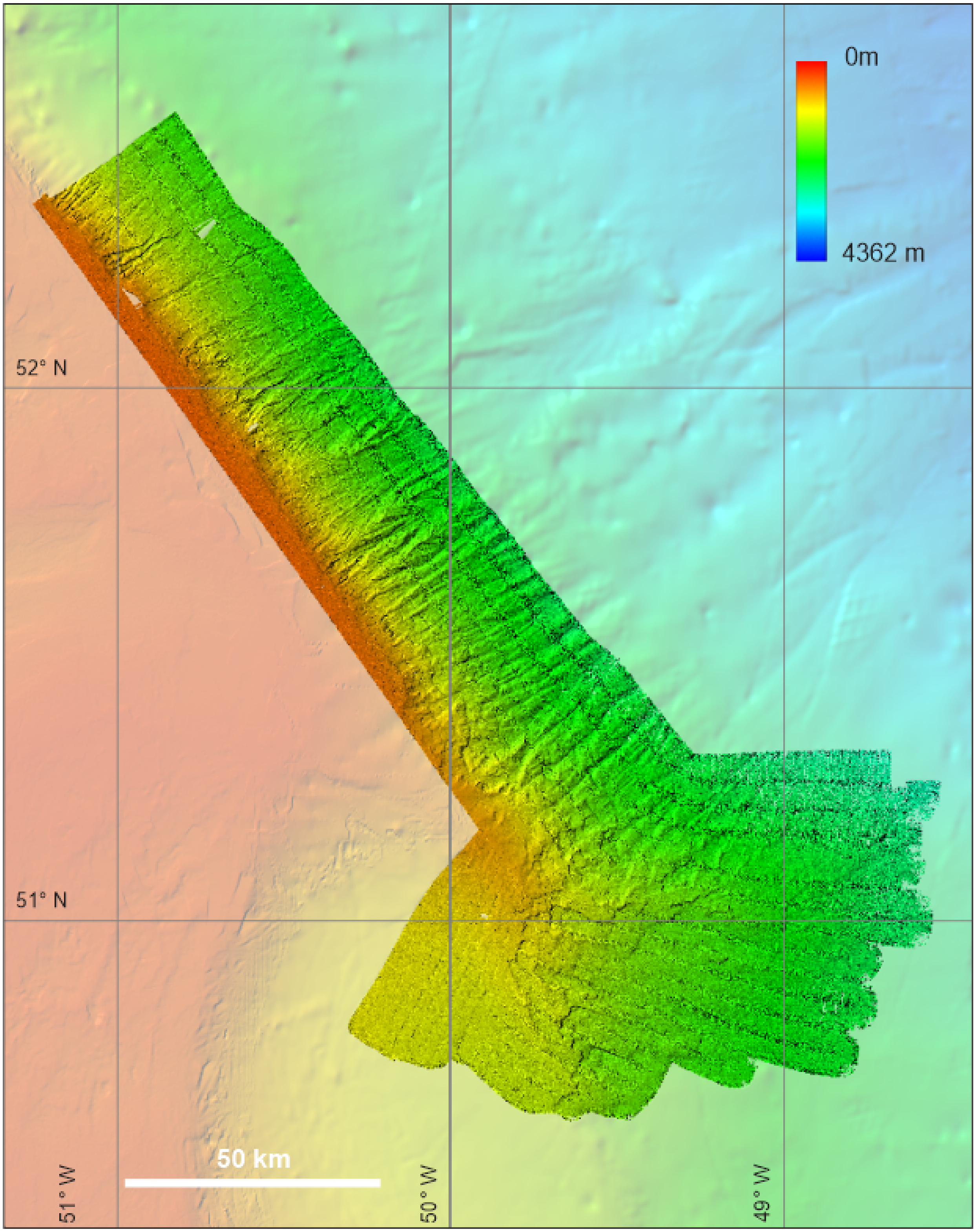

Figure 9. Overview of the multibeam bathymetry coverage collected during the cruise (saturated colors) overlaid on coarse resolution bathymetry compiled from historical single beam and multibeam data (pale colors).

The survey gave new insight into surficial geology, geohazards and benthic habitats of the Northeast Newfoundland slope, the northern part of Orphan Basin and Orphan spur. The upper part of the shelf break is heavily scoured by multiple generations of iceberg–seabed interactions (from the shallowest survey part of 400 meters to approximately 680 m water depth). The majority of iceberg scours are semi-parallel to the shelf edge, oriented from NNW to SSE and range from 100 – 200 m wide and tens of km long. Their depth distribution suggests that they are not modern, but originated during deglaciation (Figure 10). In northern Labrador, Saglek bank shows modern iceberg scouring to depths of 220 m while relic iceberg scours could be found to 300 m water depth (Todd et al., 1988). The deeper extend of relic scouring is explained by the low sea level stand during late Wisconsinian glaciation, estimated to be 120 m in the region of Grand Banks (Fader 1989). Judging by the depth of scouring the lowstand in the survey area could have been even lower than elsewhere in the region.

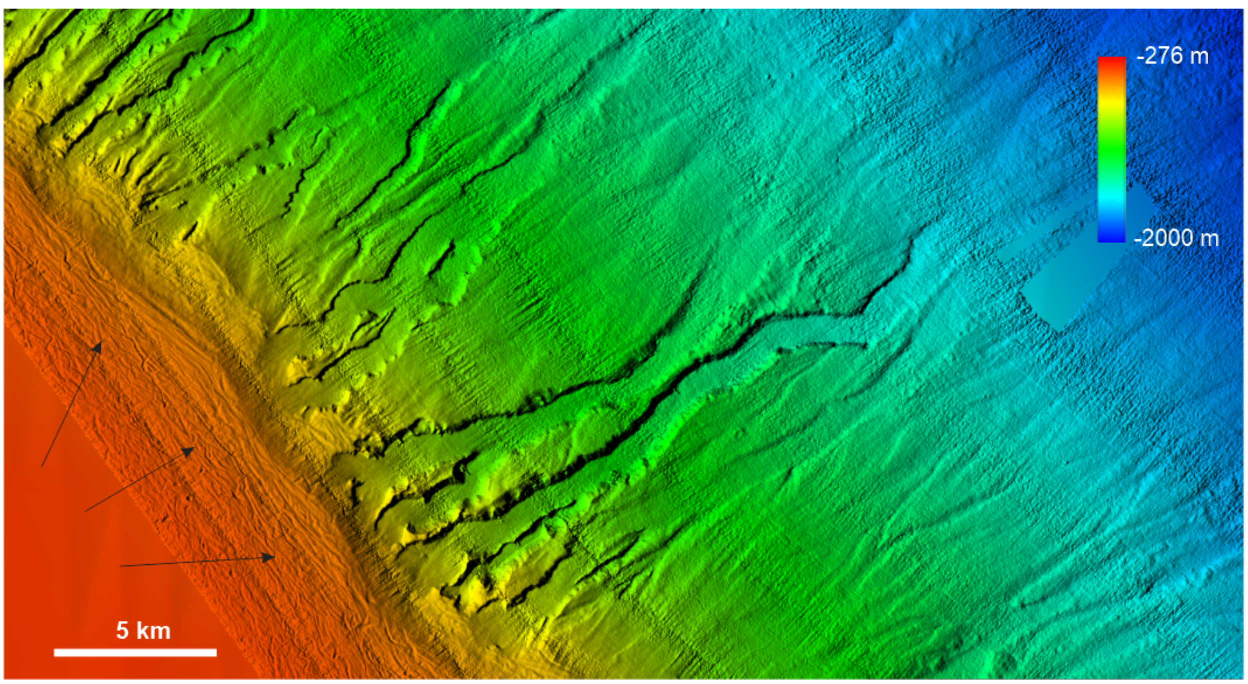

Figure 10. Northern part of the survey area showing dense populations of iceberg scours (black arrows) and shelf-edge gullies.

In the north, proximal to Notre Dame Channel, the upper slope is incised by U-shaped gullies several km wide, with flat bottoms and with walls reaching 100 meters in height, possibly resulting from relatively recent erosional processes. However, the future coring of these features may show that their age is underestimated because of the lack of net sediment deposition. Most of these terminate at 1500 – 2000 m water depths, within a relatively featureless lower slope. The southern part of the survey area shows a more convoluted and eroded shelf break, with massive slumps overlaying V-shaped canyon valleys continuing onto deep water (2500 m and deeper). There are indications of fluid escape features (pockmarks) and evidence of more recent smaller scale debris flows (Figure 11 and Figure 12).

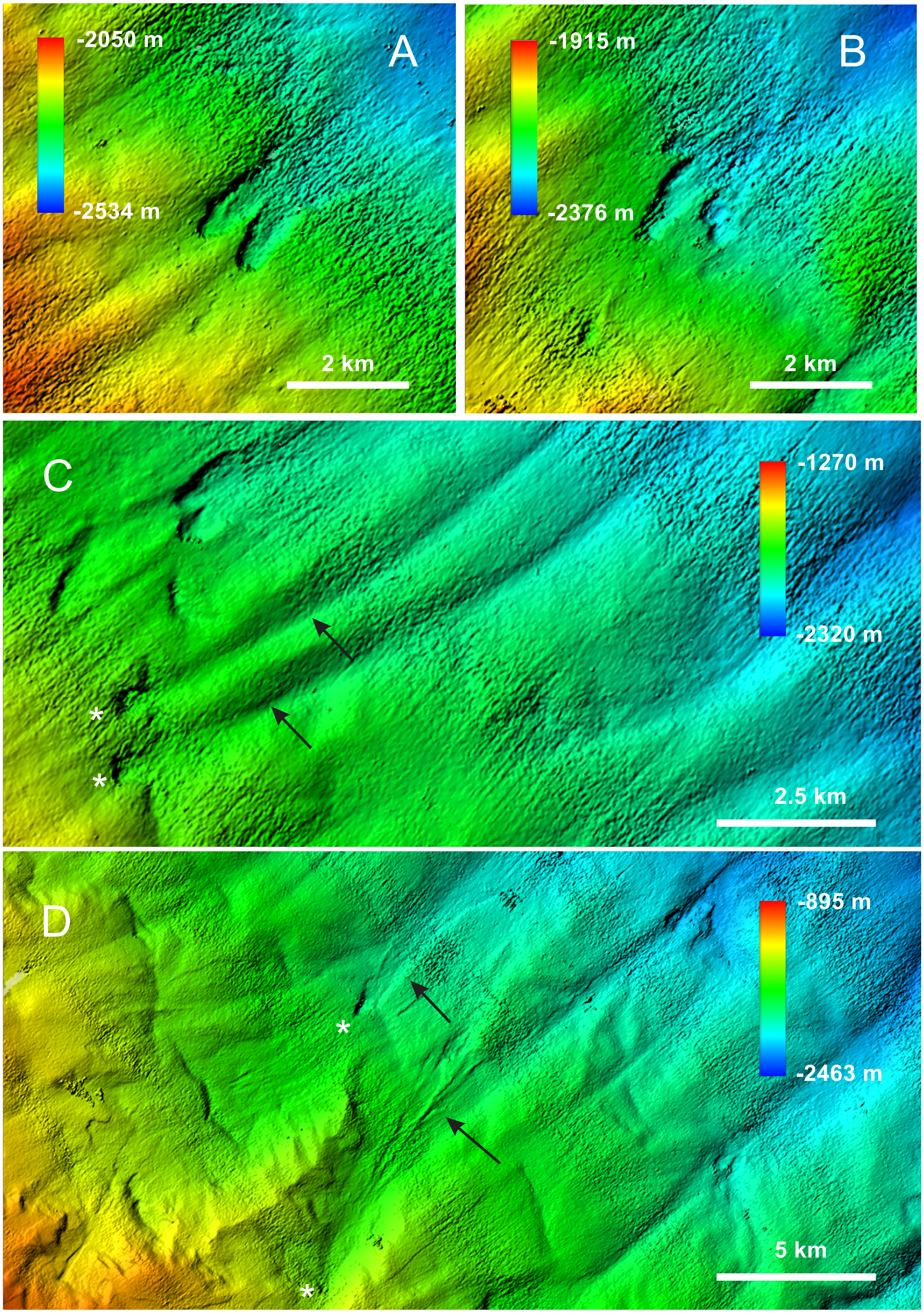

Figure 11. A and B: Examples of pockmarks observed in the survey area. C and D: Pockmarks (indicated by asterisks) which possibly serve as nucleation sites for initiation of downslope sediment movement and canyon development (arrows).

Pockmarks deserve special attention because they could be indicative of the leakage from an active hydrocarbon system and could pose a hazard for seabed engineering projects. The pockmarks were approximately 500 m across, elliptical, elongated downslope, with the lower berm gradually blending into surrounding seabed, commonly appearing in fused pairs (Figure 11). It seems likely that in several cases the pockmarks served as nucleation sites for downslope sediment movement and for progression of canyons upslope (Figure 12).

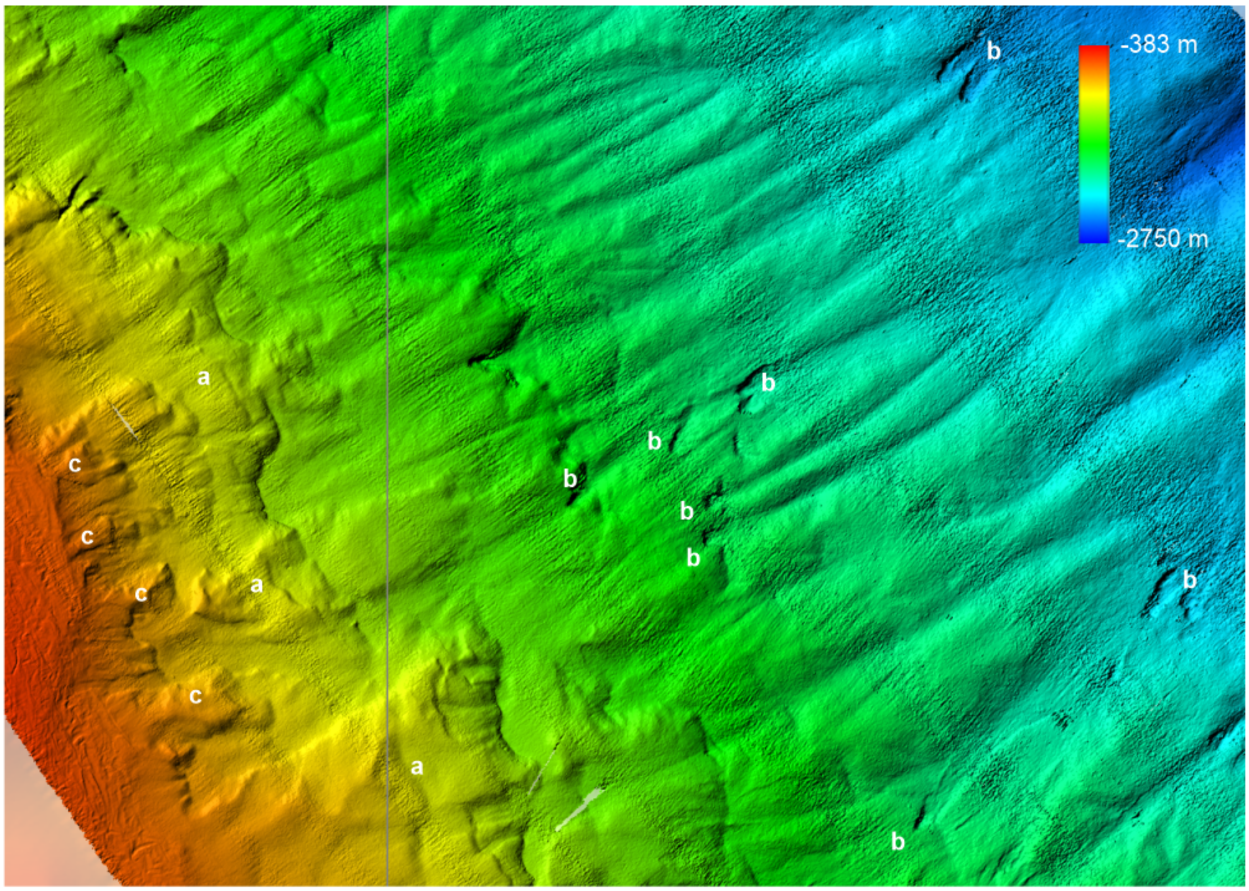

Figure 12. South-eastern part of shelf break next to Orphans Spur showing massive slumps (a) fluid escape features (b) and truncated spurs (c).

The area of Orphan Spur has experienced recurrent slope failures, as evidenced by long, massive and multiple escarpments, mass transport deposits and block failures. High-resolution bathymetry reveals Orphan Spur as exhibiting a series of large-scale retrogressive slope failures, that have been subsequently overlain by approximately 10 m of sediment (Figure 13). The deeper part of this area is characterised by many "pagoda-like structures" – acoustic masking of sediment stratigraphy through the top 40 meters, indicating the possible presence of carbonate mounds (Figure 14). These structures extend approximately 5 m above the surrounding seabed and are approximately 300 m in diameter. It is, however, possible that these features are an apparent artefact resulting from the acoustic response from the buried failure surface.

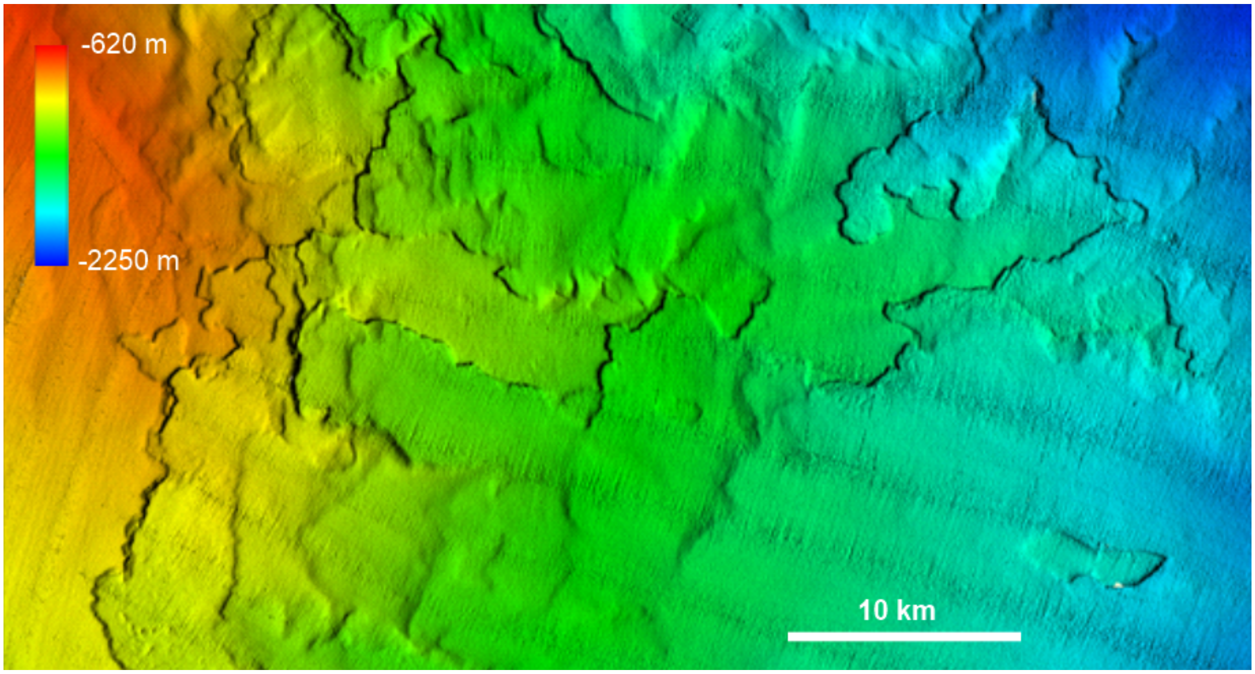

Figure 13. Orphans Spur, a system of massive escarpments and multiple generations of slope failures.

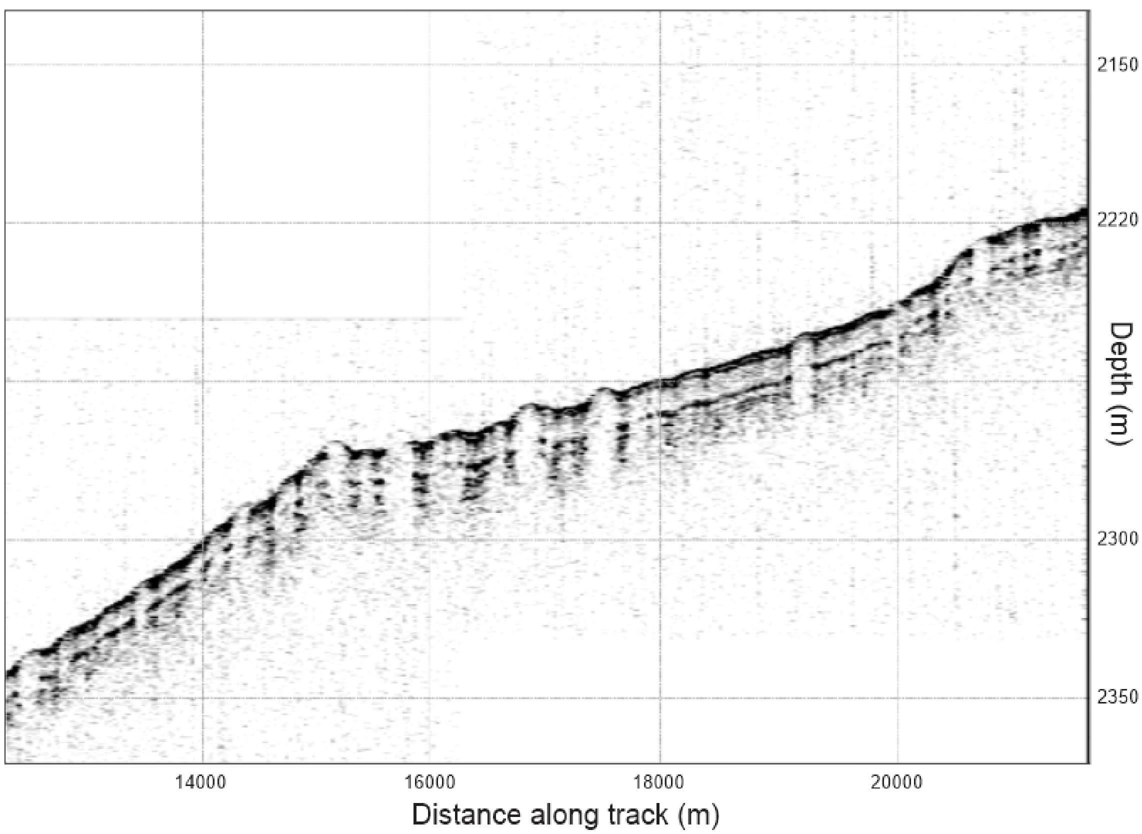

Figure 14. Pagoda-like features off Orphans Spur.

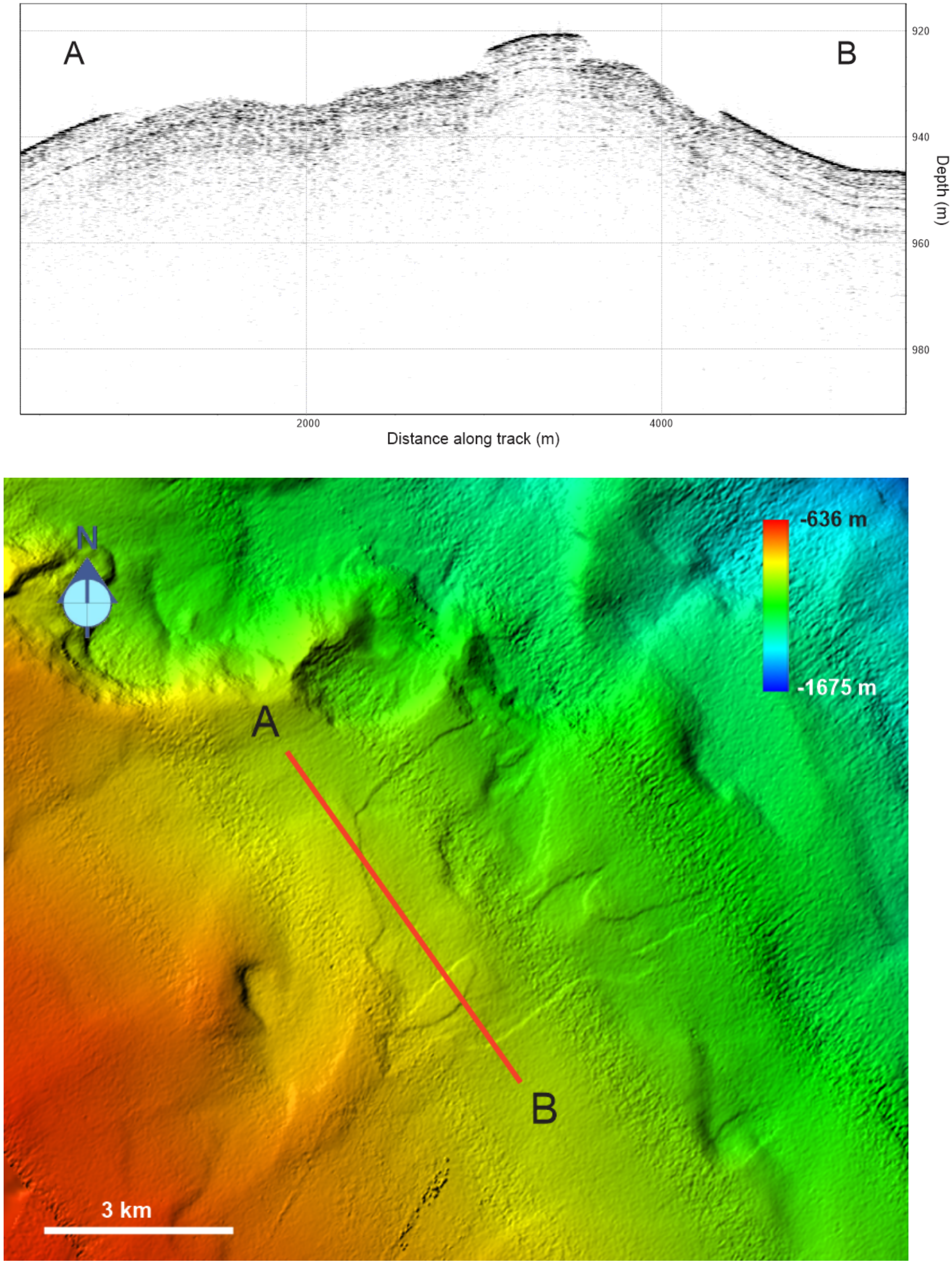

Figure 15. 3.5 kHz sonar record (top figure) and corresponding track (red line, bottom figure) over multibeam bathymetry showing a recent failure. Note that about 3 meters of the highly reflective surficial layer of sediment is removed over the area of failed sediment.

A very preliminary examination of the new findings cast light on both the conservation value of the region as well as a wide range of geological hazards, including possibly very recent slope failures (Figure 15). These features show no sediment cover above the resulting mass transport deposit (MTD) in 3.5 kHz sub-bottom profiler data, suggesting they are potentially recent. The newly collected data help understand risks related to hydrocarbon exploration (e.g. drilling) in steep, irregular terrain, with potentially unstable seabed slopes. The widespread features interpreted as carbonate mounds indicate the possible presence of live deep-water coral colonies. Both findings support the sensitivity of this area to any type of bottom-contacting human activity.

The expedition has demonstrated successful collaboration between the Canadian Hydrographic Service and the Geological Survey of Canada. The collaboration helped saving on shipping costs for mobilisation and demobilisation of gear to and from St. John's because our gear was added to DFO's cargo. Otherwise, we would have used up to three tri-walls for shipping. The CHS team carried out MB acquisition, quality control, cleaning and preliminary processing while on board. This allowed stepping off the ship with readily available bathymetric models for the area.

As a result of this expedition a follow-up ground-truthing cruise was planned for the summer of 2020, aiming at collecting physical samples (grabs, cores), video and photo data as well as high resolution multibeam bathymetry using an autonomous underwater vehicle in the identified locations of interest, e.g., carbonate mounds, escarpments, debris flows, for the purpose of identification and dating these features.

ACKNOWLEDGEMENTS

We are thankful to Captain Wayne Duffet for ensuring a successful survey. His experience, interest in the science and suggestions on operations were much appreciated. The officers and crew of LSSL were most helpful and engaged in our work. We also thank Laura Broom for a thorough review of the report and her helpful suggestions.

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APPENDIX A: Daily log of events

The daily log was merged and modified from the chief scientist's and the chief hydrographer's (King 2019) notes.

Friday August 2 2019

Scheduled departure was adjusted from August 1 to August 2 as per direction from Captain Duffet. CHS and NRCan personnel arrived in St. John's, Newfoundland August 2 and proceeded to embark on Louis S St-Laurent (LSSL) at berth 17 at 15:50. LSSL had already completed bunkering mid-week. Despite high hopes, a expected 20:00 departure was postponed till 12:30 next day as the ship was waiting for the last of crew arrival (Friday afternoon). Personal gear was secured in assigned cabins; familiarization and walkthroughs commenced at 17:30. Sunny calm weather.

Saturday August 3 2019

Morning weather – clear, wind 10 knts. Kostylev met and discussed plans with Captain Duffet. Departure revised for 12:30 local as 2 crew members arrived Friday afternoon. Wharf side fire and boat drills were conducted at 10:20. After letting go the lines at 15:30 UTC, compass calibration was conducted mid harbor. Passage through the narrows occurred at 14:30 local. Meslin and Manning finalized setup of Knudsen system and Regulus. Kostylev and chief engineer identified locations of IMU and 3.5 kHz sonar (184 feet from stern). Transit commenced to the winch testing location 230 nm NNE of St. John's harbor. The winch test for Leg 2 JOIS requires 450 m depth. The EM122 and POSMV were started without any issues. First line started at 17:10 UTC, logging at 20:53 UTC. At 20:40 took course at 062 to the first waypoint. ETA – 9:00. The mammal protection option was used on pinging start-up and range set to 100m. Transit data was logged overnight both multibeam and sub-bottom profiler. Stephen Nunn conducted an OHS worksite review for those ship areas used by CHS/DFO personnel (quarter deck, survey room, forward hold). Meslin and Manning stood alternating 12 hour shifts (8:00 – 20:00 and 20:00 – 8:00 correspondingly).

Sunday August 4, 2019

A program overview meeting was held Sunday morning with LSSL Captain, Officers, and CHS and NRCan staff 8:30 local time. Vladimir Kostylev delivered the NRCan program objective. This was followed by CHS presentation of the primary area (NE Baffin) for multibeam data collection and retrieval of two submersible tide gauges from the same target area.

The JOIS winch test commenced at ~9:30. CHS took advantage of the opportunity by attaching our Minos X SVP. By 10:26 local the test was concluded with no issues and the Minos removed for data recovery.

The ship location after the winch test was just South of the first survey area starting point.

At 11:10 the ship changed course first for Bonavista, then 18 knts to St. John's as a CCG crew member medivac was required. Fog and distance precluded medivac by helicopter. Operational experience/training with software and equipment continued with Steve Nunn and Justin Fizzard.

Monday August 5, 2019

At 00:30 local time 1 CCG crew member was sent ashore by RHIB at the approaches to St. John's. Underway by 01:00, steaming at 17 knots back to the Area 1. Multibeam and water column files have been logged as reconnaissance data. 3.5 kHz sub-bottom data were logged simultaneously. 14:30 local time was the start time of Area 1 data logging after an expendable SV probe was deployed at the starting location. Speed was 10 knots to start for the NRCan Area 1. The baseline depth is 550 m on average with a 90 nm run at 325 degrees T.

NAVWARN review started on the Saturday transit data. Review will be ongoing daily to meet the 2 day standard. While none area expected at deeper depths, this gives us a training opportunity for Justin Fizzard to learn HIPS Subset Cleaning for outlier QC. Steve Nunn will be refreshing his HIPS experience also. Sara Graham is our lead processor for Leg 1. CHS technician David Levy has installed, modified, and adjusted all our equipment needs. Patrick Meslin and Dez Manning has set up and tested all 3.5 kHz equipment and acquisition software. Foggy, 10 knt wind.

Tuesday August 6, 2019

We continue to process the previous day's MB during the overnight. Sara Graham had created both 10 m and 20 m resolution csar surfaces for NRCan. An expendable SV probe was deployed at 7:04 local. Logging continues uninterrupted all day. NAVWARN/outlier review for Sunday complete and Monday commenced. An attempt to increase speed to 12 knts did not work out as sea state combined with steep irregular gully channel features on the shelf edge succeeded in confusing the EM122 swath. Speed was reduced as were coverage angles. 2 xSVs were deployed successfully, 1 dud. Foggy, moderate wind.

Wednesday August 7, 2019

Continuing logging non-stop all day. 2 xSVs were deployed successfully. 4 small bad data areas on the previous evening's line were replaced by performing short racetrack manoeuvres from the adjacent return line. Data collection continues uninterrupted all day. Foggy in the morning, then clearing in the afternoon and turning to overcast later at night. Calm.

Thursday August 8, 2019

For consistent backscatter intensity range, MB had been logged regularly at "Medium" mode (450-1000 m depth) until today up to 1100 m. Early morning the setting was adjusted to Deep mode. Working east to 2000 m depths we will continue with Deep setting. Foggy weather, calm seas.

Friday August 9, 2019

Continuing surveying Area 1. BIST run at EOL mid-afternoon. EM122 nominal. POSMV remains rock solid. 3 xSVs deployed today. We are moving on during the graveyard shift to Area 2 Friday night/Saturday morning. The skies are clearing.

Saturday August 10, 2019

Foggy. Wind 25 knts. Building seas. Line running E-W commenced at 7:40 local. 2 xSVs deployed. Moderate winds with low swell.

Sunday August 11, 2019

Stormy with ~3 m seas. POSMV restart at 00:00 UTC. 11:31 local time - power loss. E-W oriented lines continue.2 xSVs deployed. Kostylev gave science presentation to the officers and crew on scientific objectives of seabed mapping in North-East Newfoundland and demonstrated preliminary results.

Monday August 12, 2019

Continuing NRCan Section 2 running WNW - ESE lines south of the E/W part of Orphan Spur. Sparse single beam 20 km line spacing data suggest both an E/W and N/S oriented spurs. Ship speed was reduced to 10 knts through the day as winds picked up 20-30 knots. Meslin and Manning continue to collect and process the 3.5 kHz sun-bottom profiler data concurrently. 2 xSVs were deployed.

Tuesday August 13, 2019

0945 local line orientation has changed to SSW/NNE. We are over the western portion of Section 2. Logging continues uninterrupted all day. Processing, NAVWARN and outlier review are meeting or exceeding the standard required. 2 xSVs were deployed successfully, 1 dud.

Wednesday August 14, 2019

SSW/NNE line running continues until 18:00 local. Conditions worsening through the day wind speed increasing to 30-35 knts. Ship speed reduced to 8-10 knts. A suitable patch test roll area was located with lines run. Pitch lines were collected later in the day. 2 xSVs were deployed. Earlier plans made for collecting more data over sparsely covered areas or areas where the bottom tracking temporarily disintegrated were adjusted due to poor sea state. We are disappointed that 3 very small areas in the Northern section and Yaw lines could not be acquired as the ship had to head for St. Anthony to disembark a crew member for medical reasons.

Thursday August 15, 2019

Transit to port commenced by 01:10 local arriving to approaches to St. Anthony at 16:00 local. Justin Fizzard (CHS) disembarked at 17:00 local with Vladimir Kostylev, Des Manning and Patrick Meslin and a Coast Guard crew member. Glen King, Sarah Graham, David Levy and Steve Nunn remained on LSSL for CHS work. Underway at 1800 Northbound for Baffin Island.

Friday, August 16, 2019.

GSC(A) team and Justin Fizzard took a commercial flight back to Halifax.

APPENDIX B: Transducer test LSSL July 23, 2019

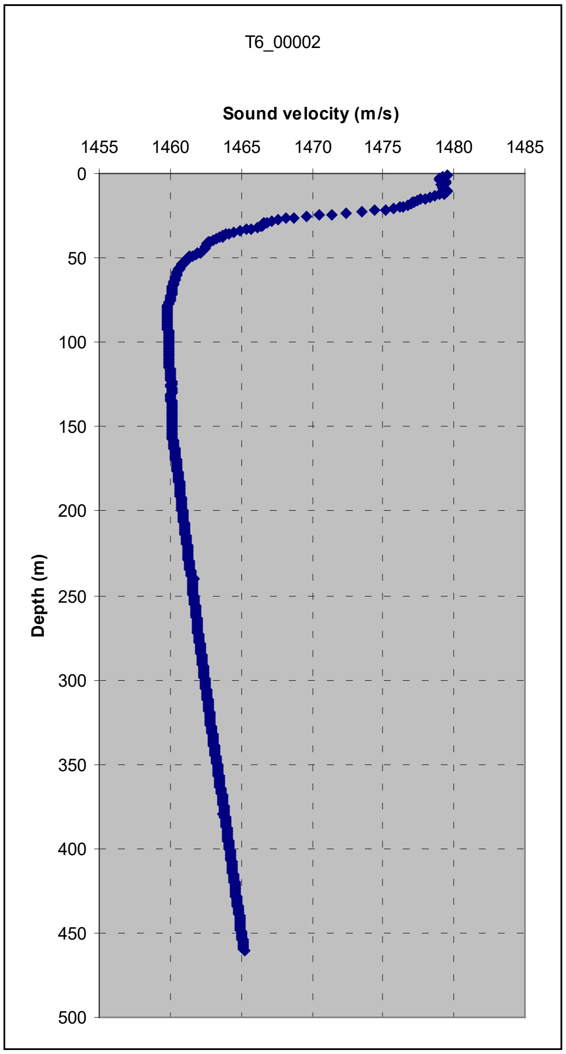
3.5 kHz:

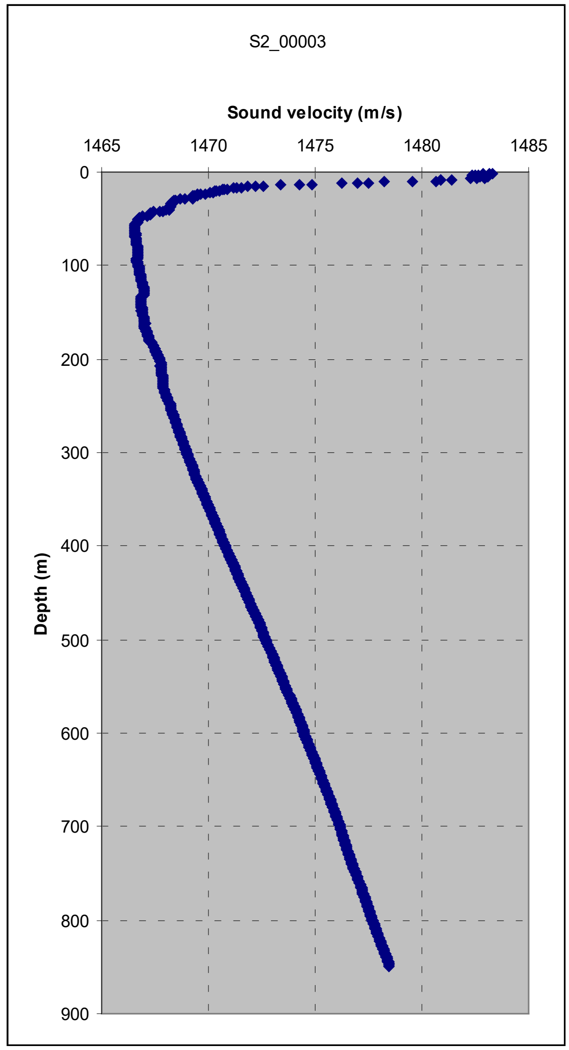
Test Frequency (kHz)	Impedance (Ohms)
2.0	500 Ω (maxed out)
2.5	297 Ω
3.0	121 Ω
3.5	110 Ω
4.0	129 Ω
4.5	116 Ω
5.0	67 Ω
6.0	135 Ω
7.5	46 Ω (?)

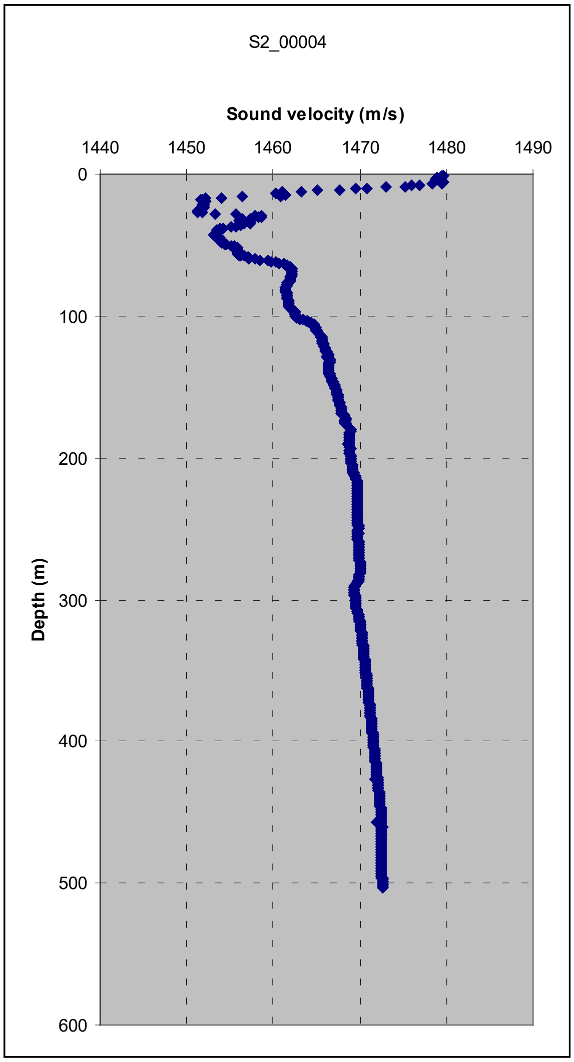
12 kHz:

Test Frequency (kHz)	Impedance (Ohms)
10.5	208 Ω
11.0	164 Ω
11.5	127 Ω
12.0	109 Ω
12.5	119 Ω
13.0	157 Ω
13.5	265 Ω
14.0	417 Ω

APPENDIX C: Plots of sound velocity profiles






S2_00004
Sound velocity (m/s)
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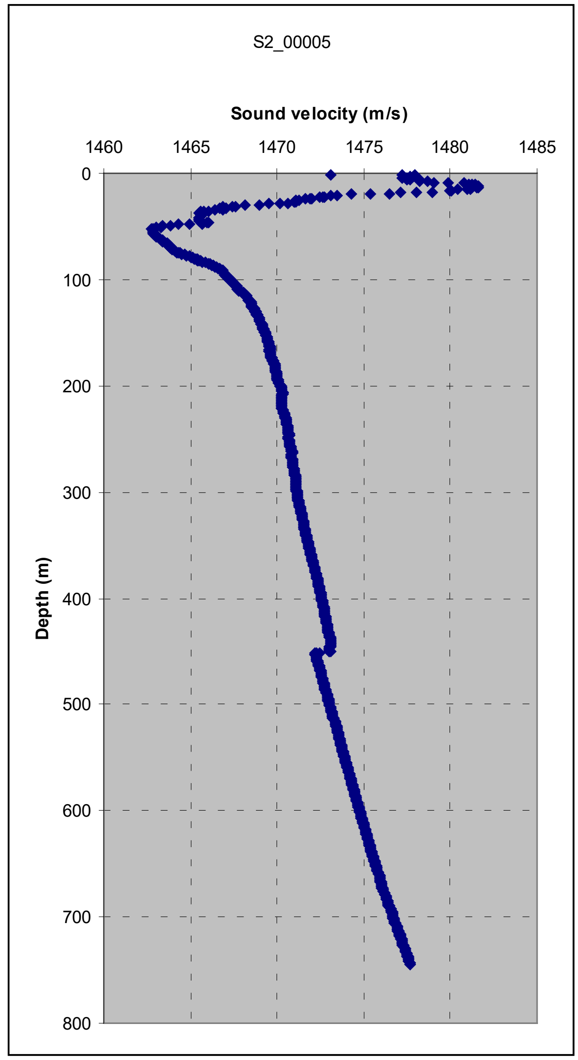
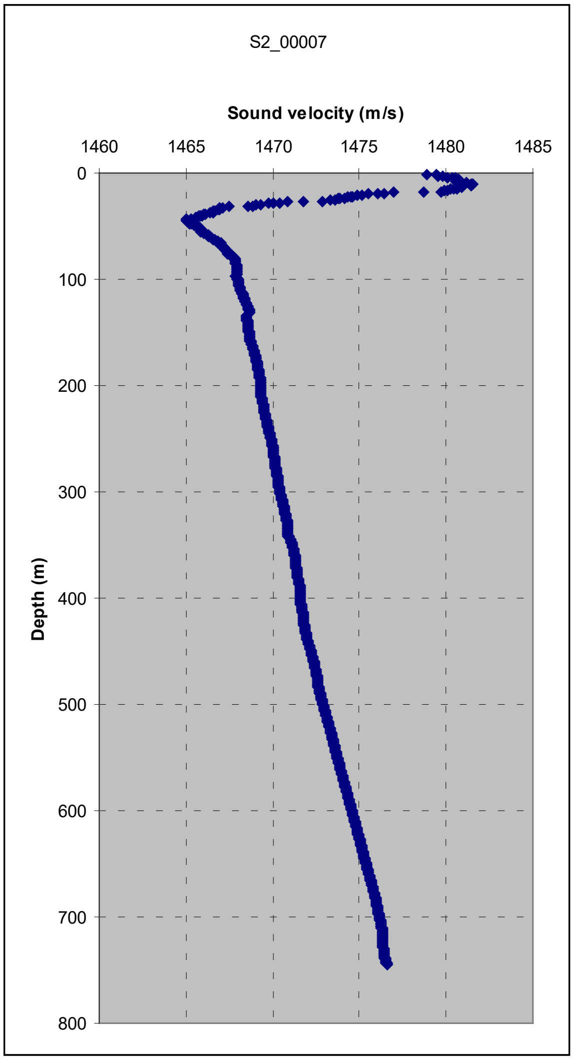
1450
1460
1470
1480
1490
Depth (m)
0
100
200
300
400
500
600


S2_00005
Sound velocity (m/s)
1460
1465
1470
1475
1480
1485
Depth (m)
0
100
200
300
400
500
600
700
800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Sound velocity (m/s)
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Depth (m)
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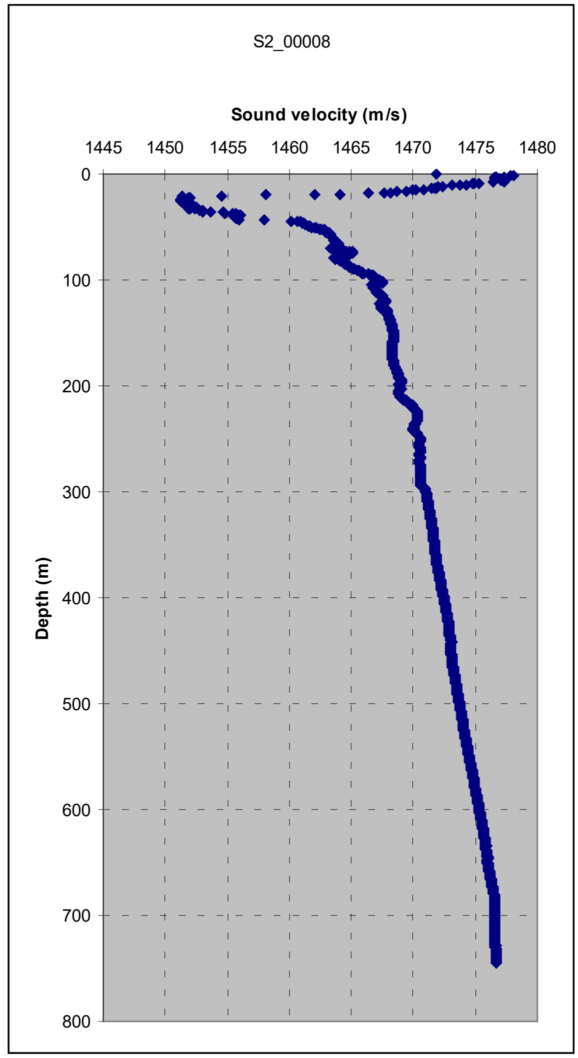
400
500
600
700
800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Sound velocity (m/s)
1445
1450
1455
1460
1465
1470
1475
1480
Depth (m)
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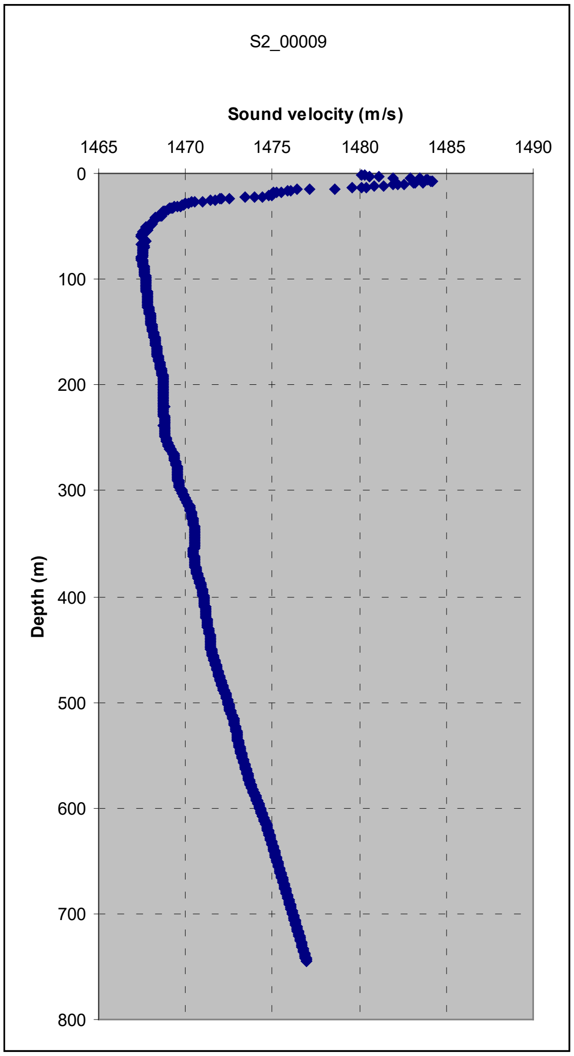
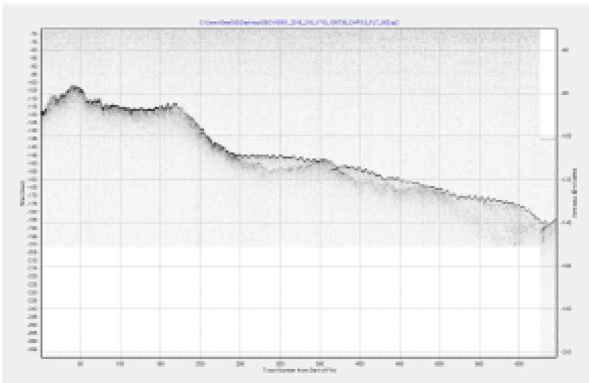
200
300
400
500
600
700
800



S2_00009
Sound velocity (m/s)
1465
1470
1475
1480
1485
1490
0
100
200
300
400
500
600
700
800
Depth (m)

APPENDIX D: Thumbnails of 3.5 kHz segments

The images are titled as the following: line number_year_julian day_start time.



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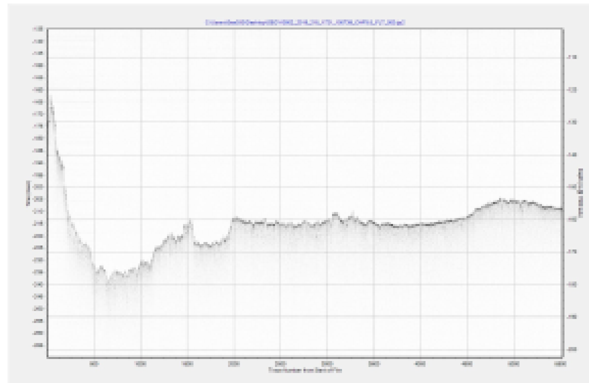

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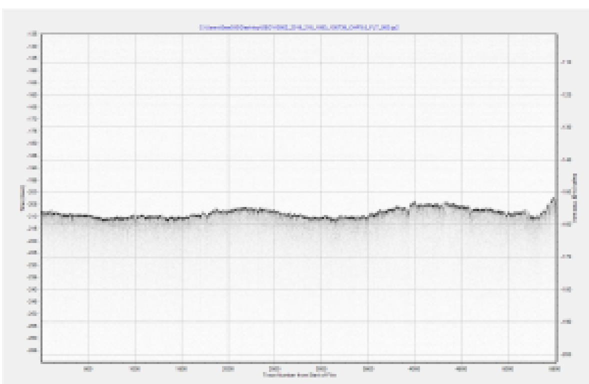

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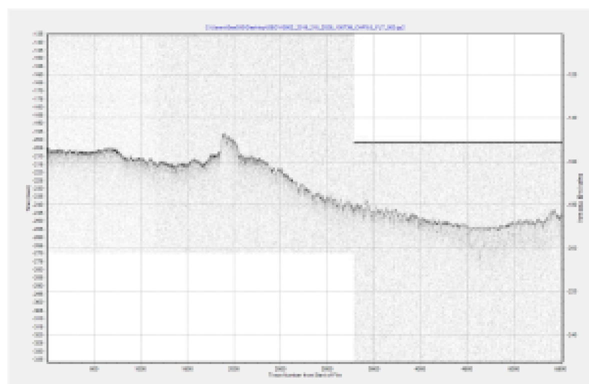

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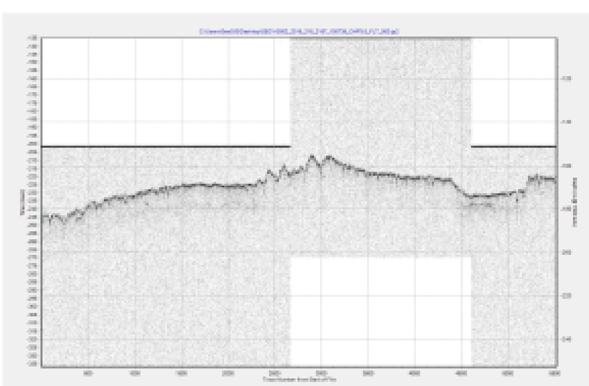

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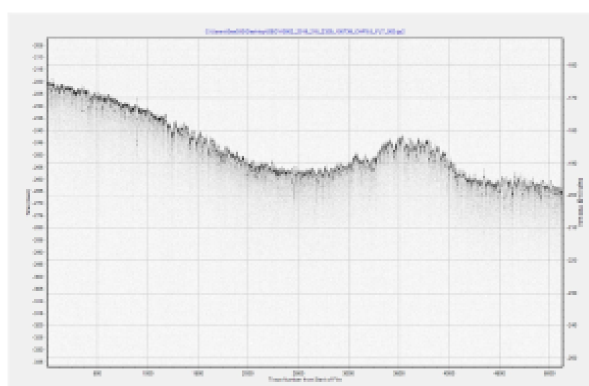

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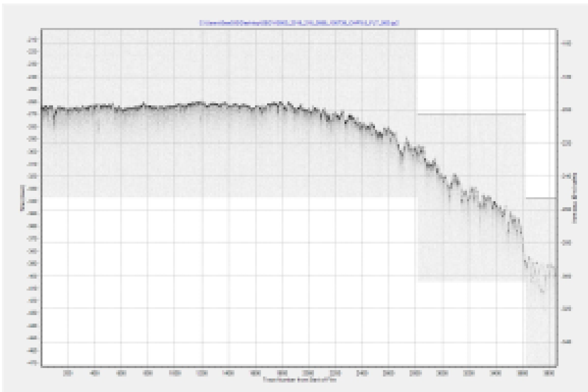
JD216



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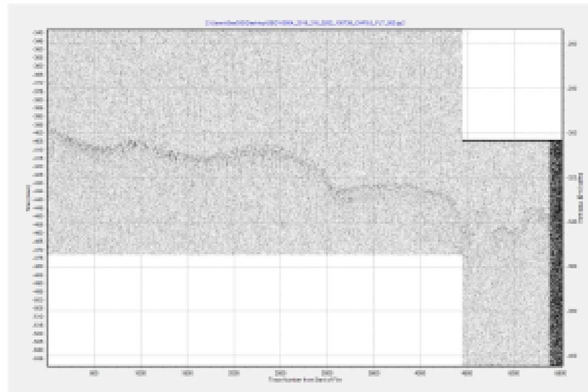

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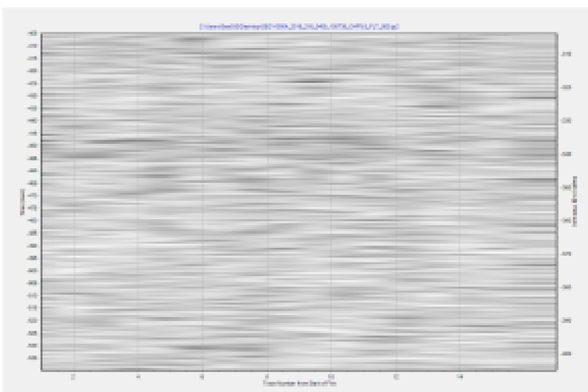

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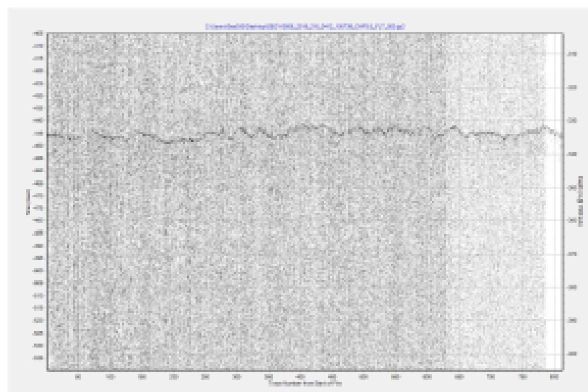

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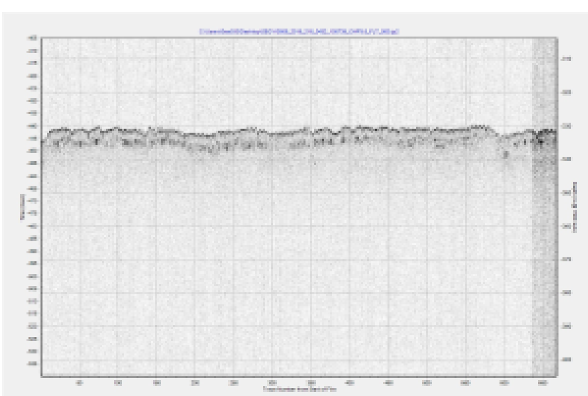

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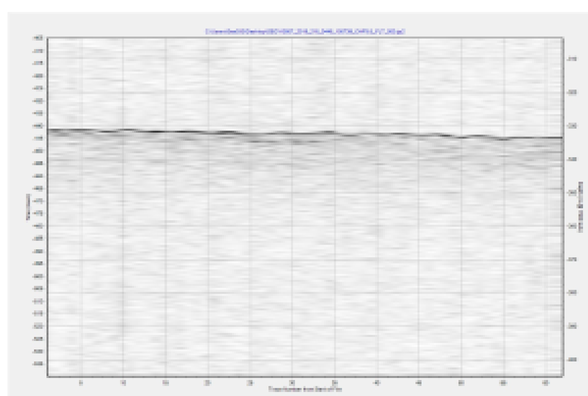

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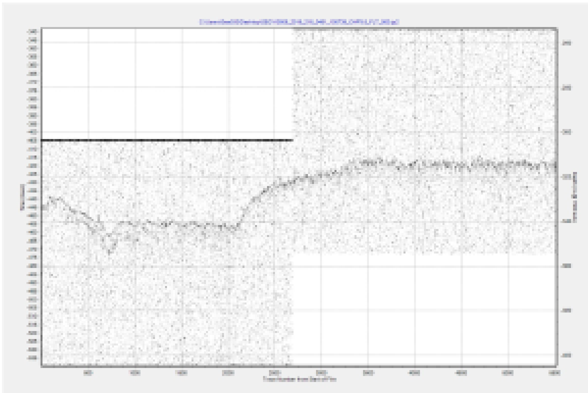

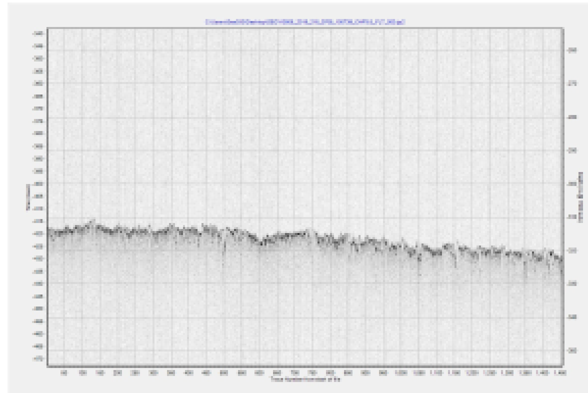

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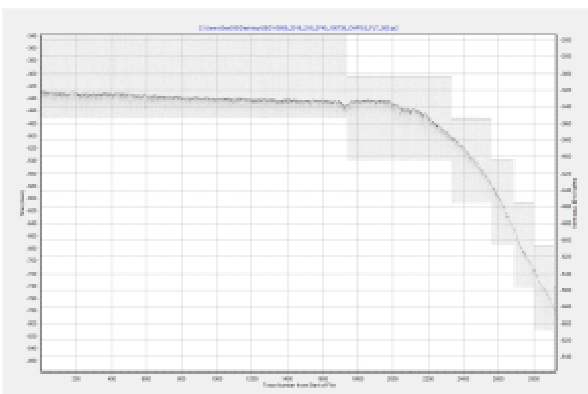

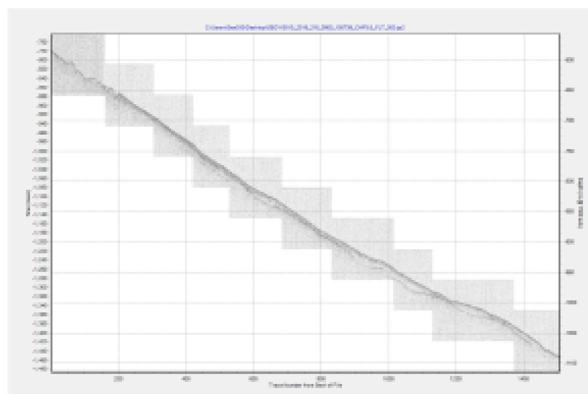

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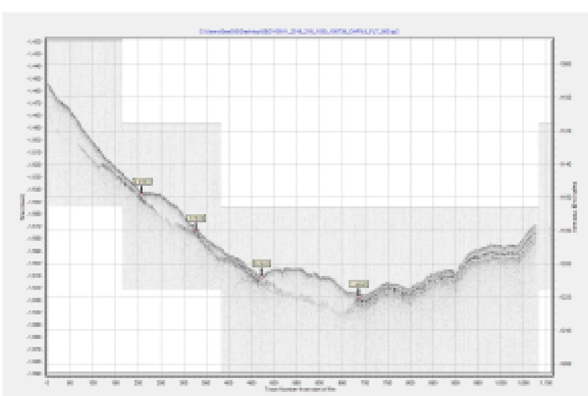

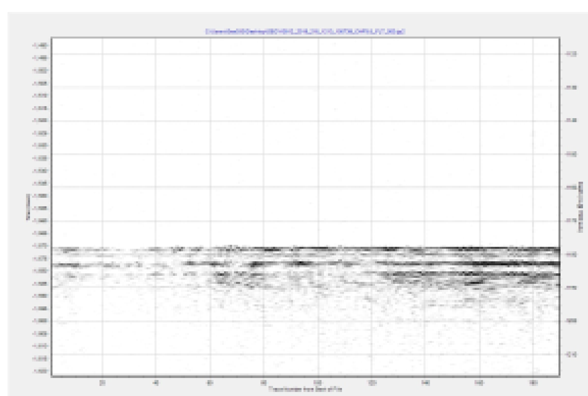

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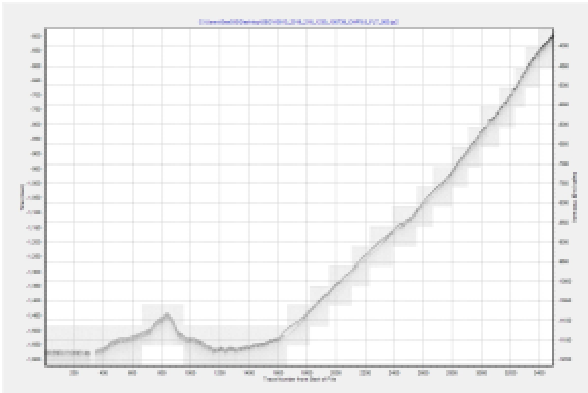

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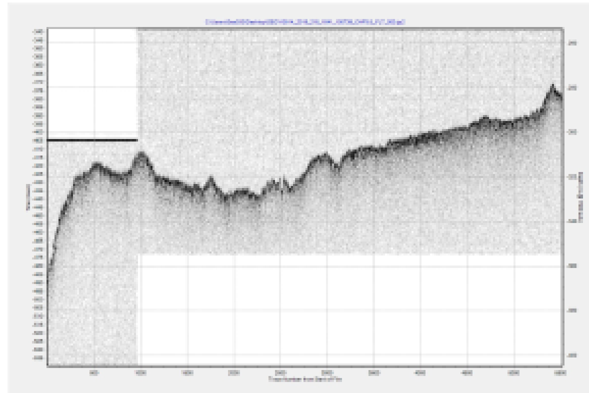

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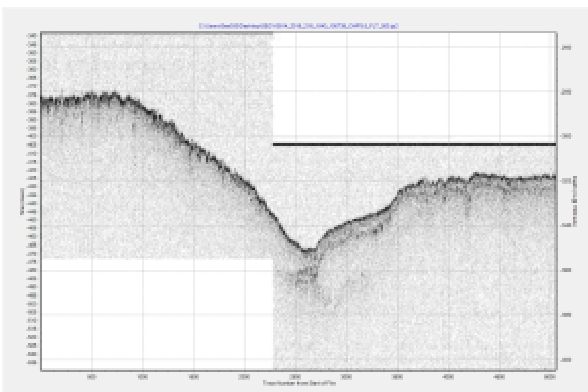

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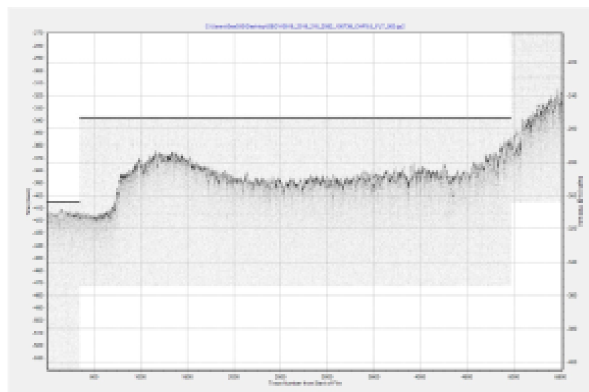

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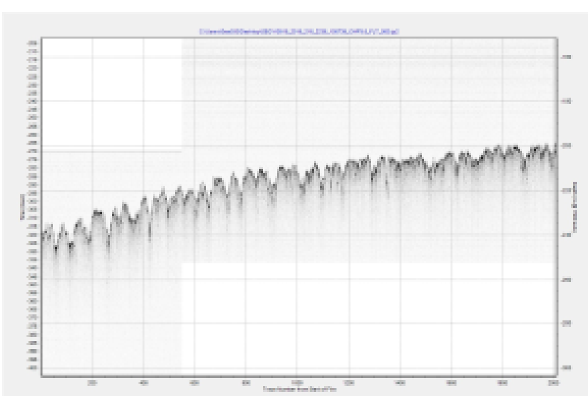

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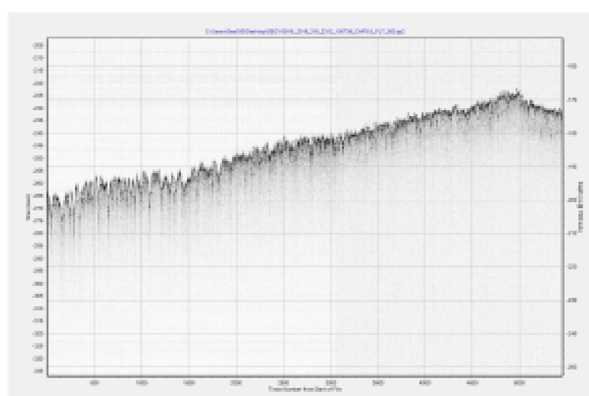

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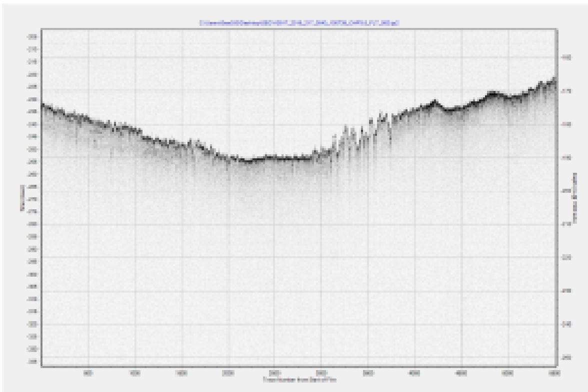
JD217



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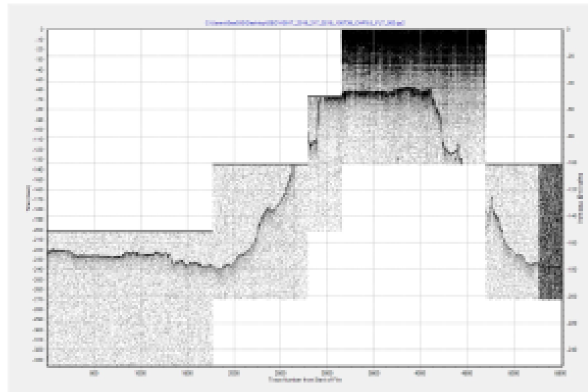

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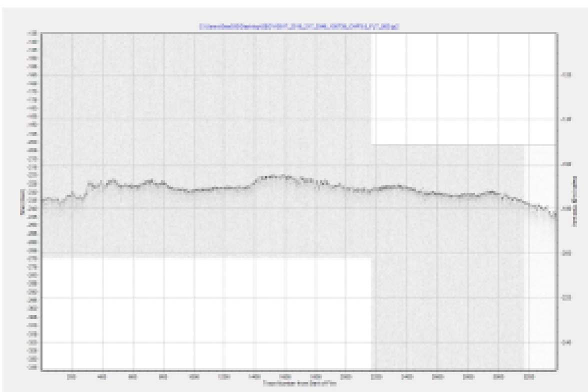

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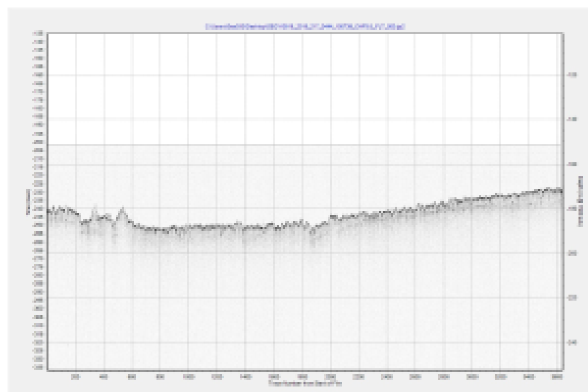

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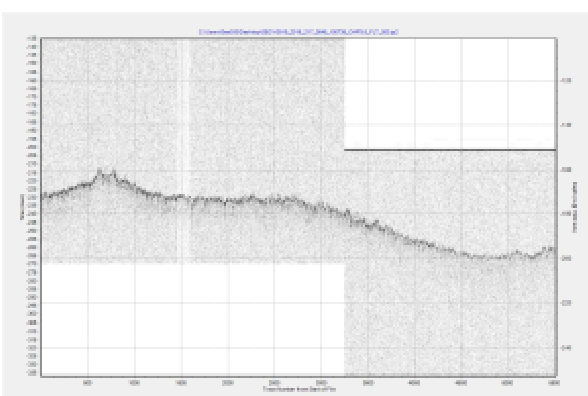

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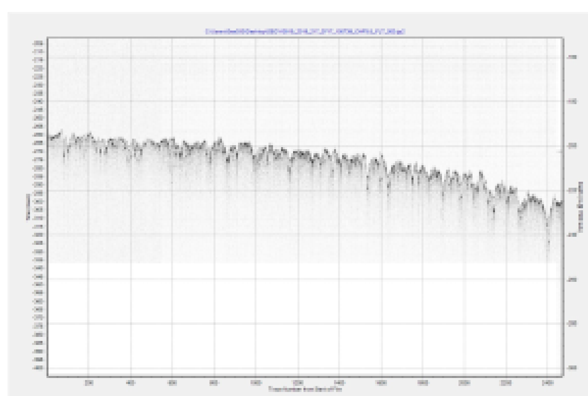

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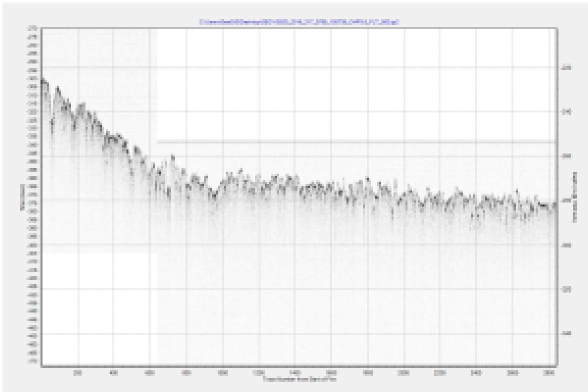

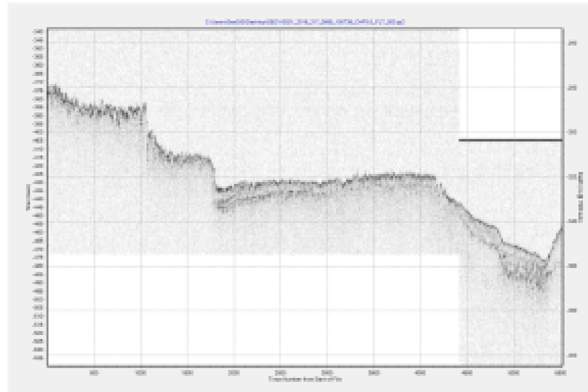

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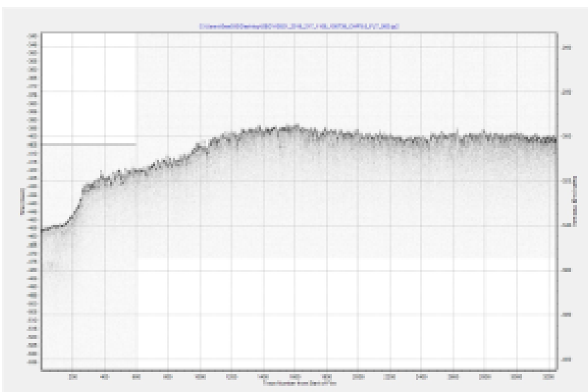

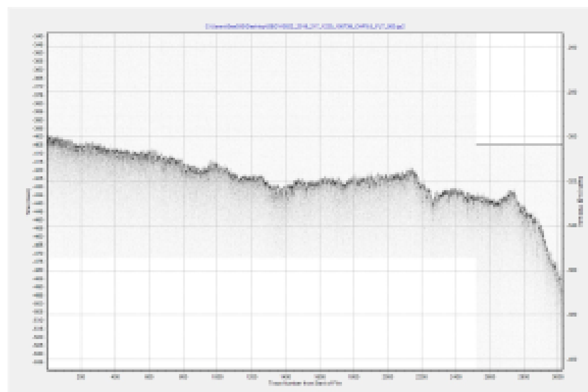

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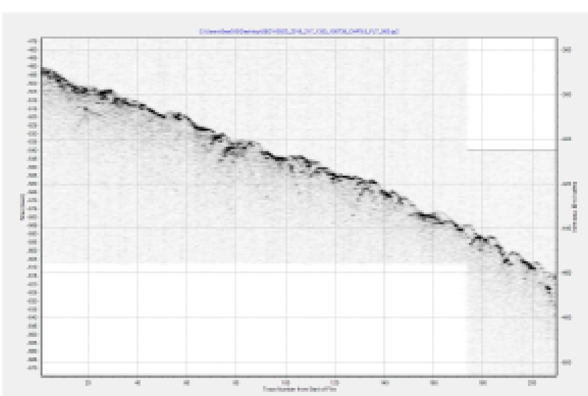

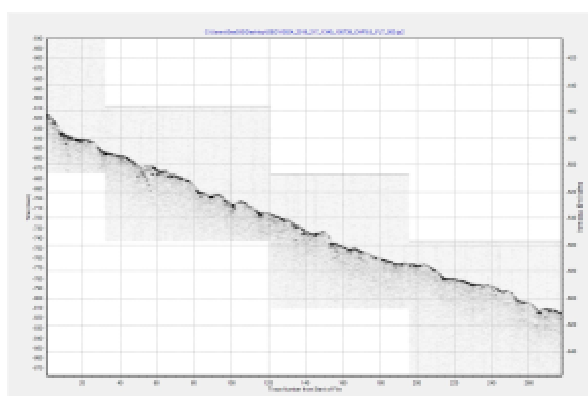

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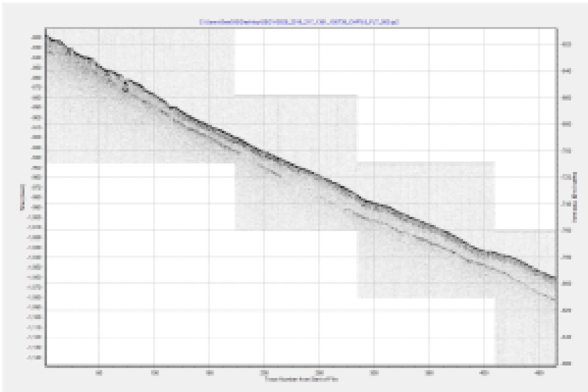

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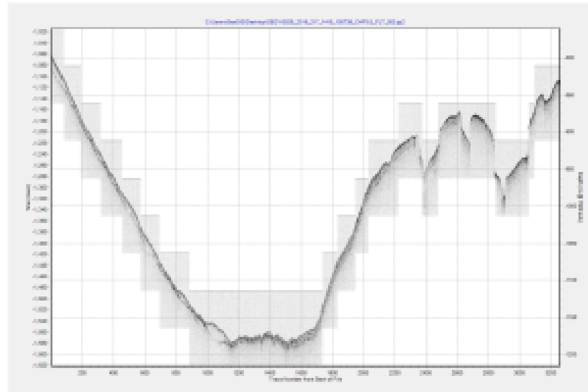

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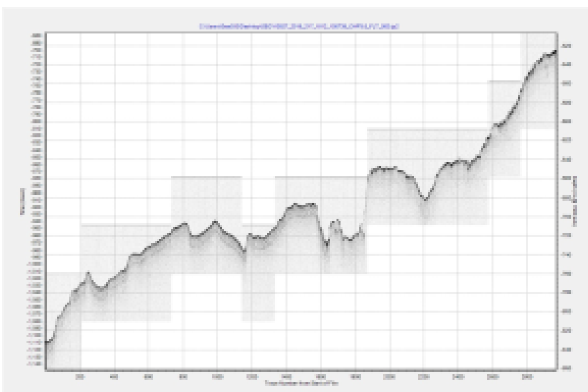

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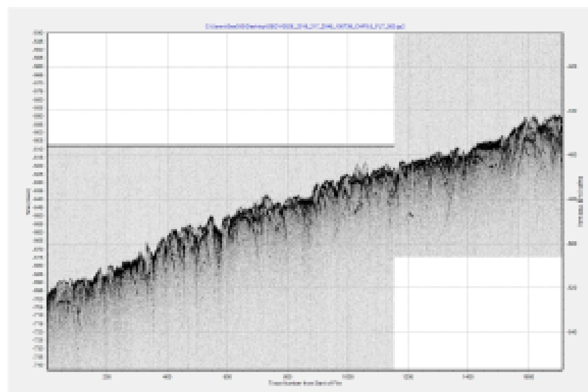

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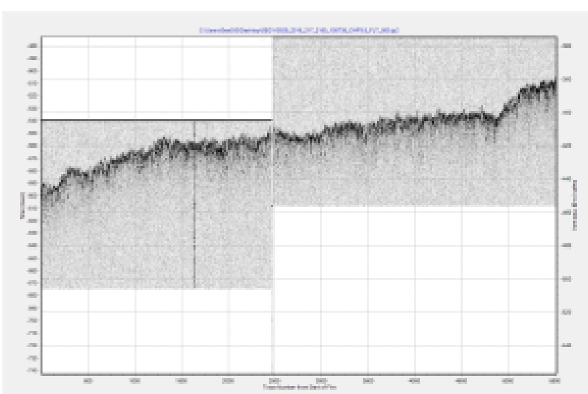

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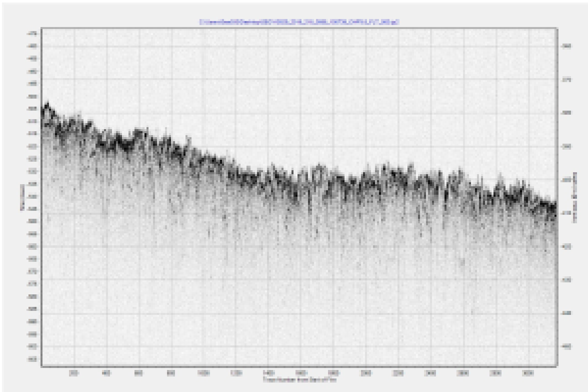

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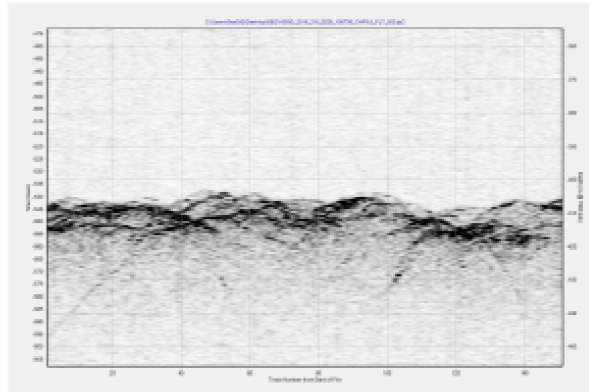

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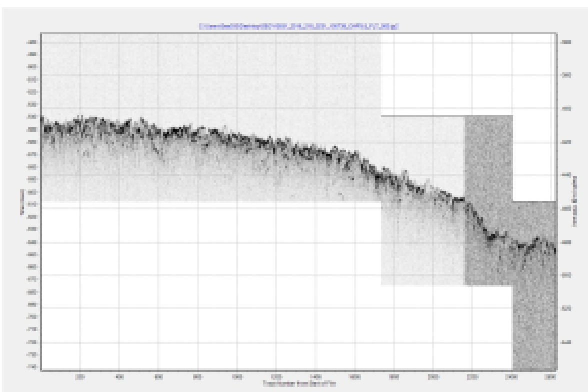

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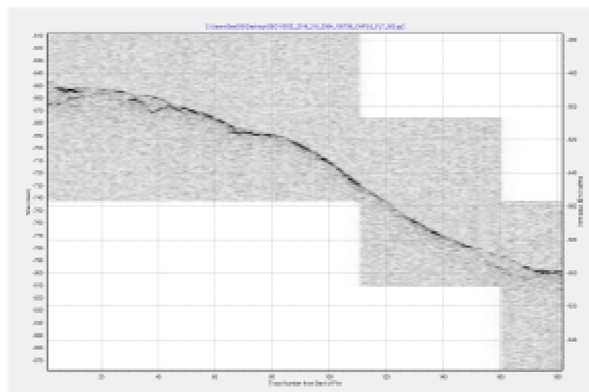

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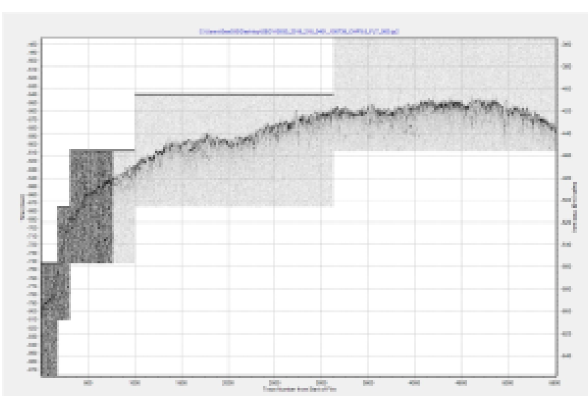

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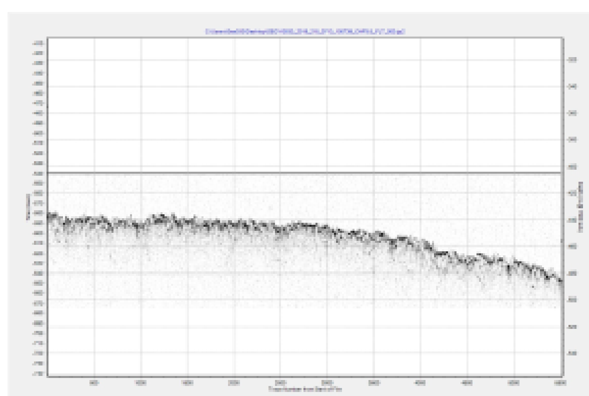

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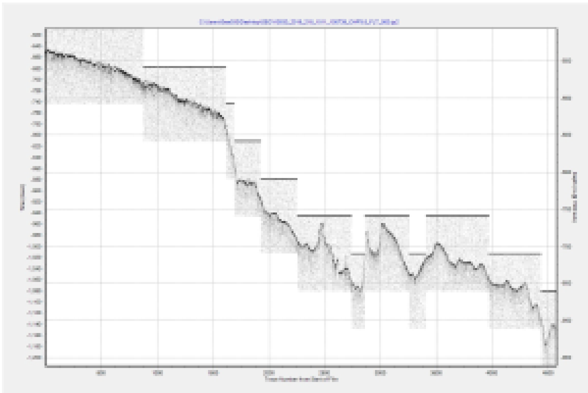

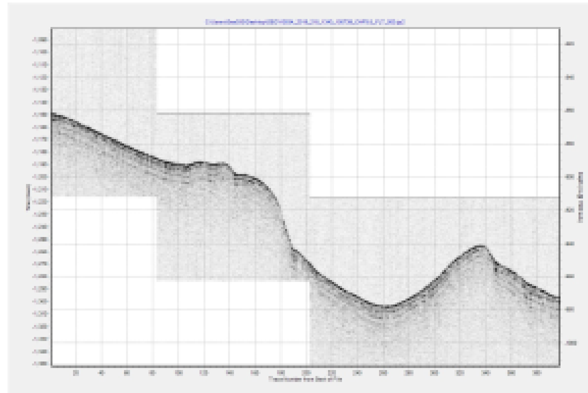

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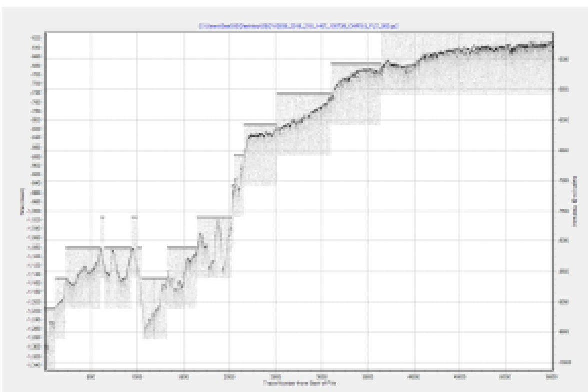

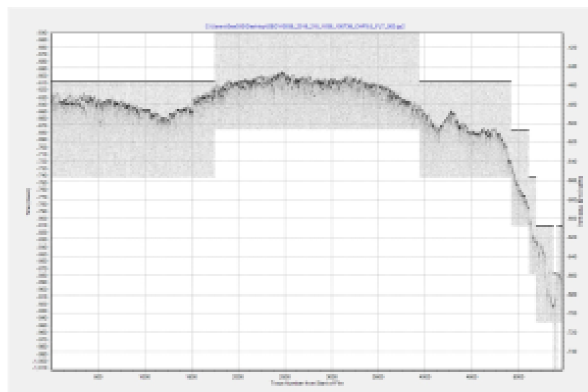

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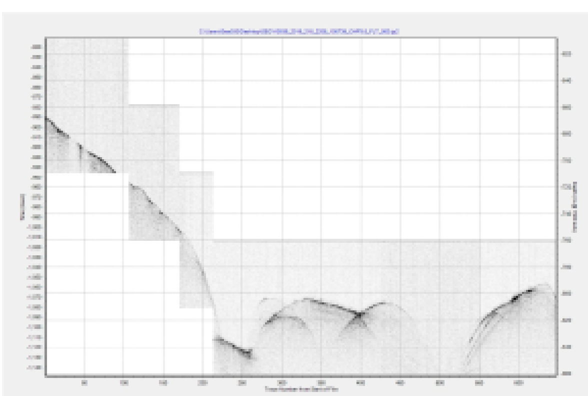

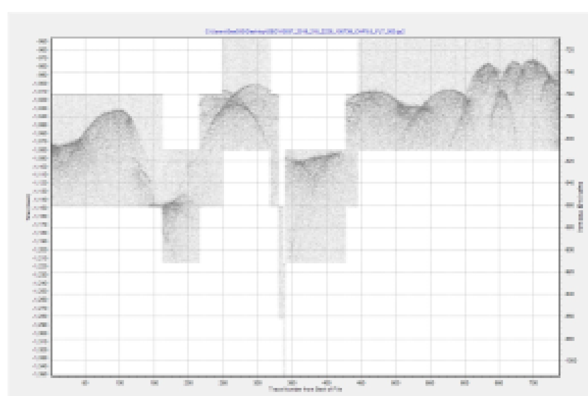

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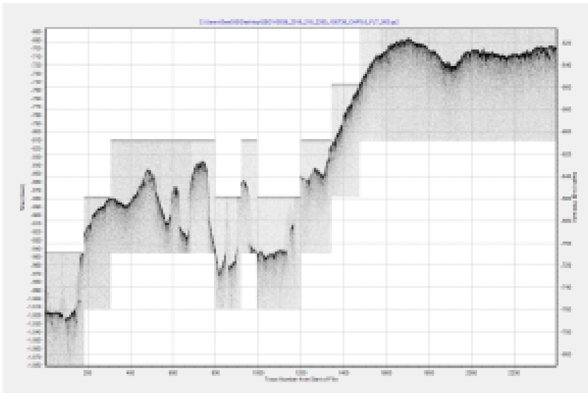

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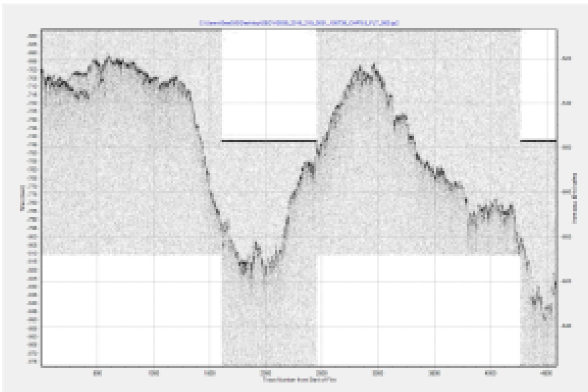

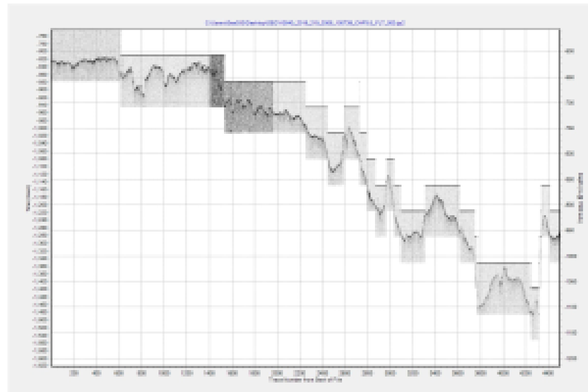

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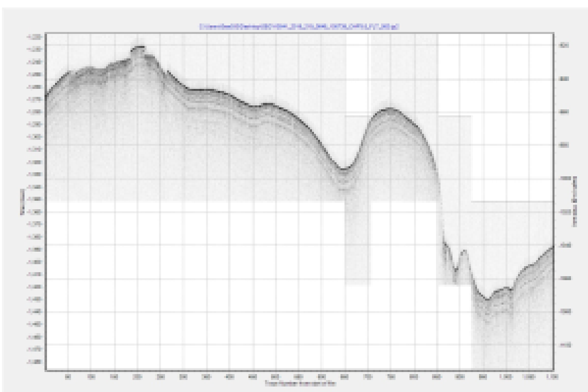

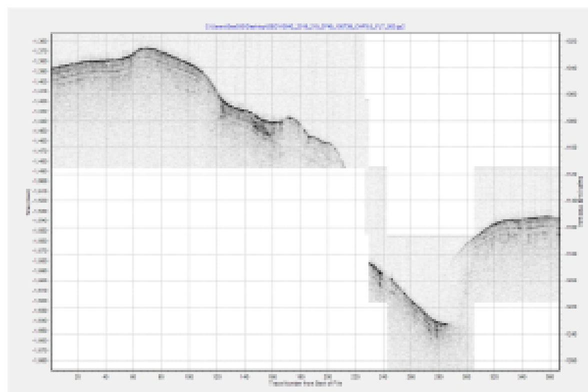

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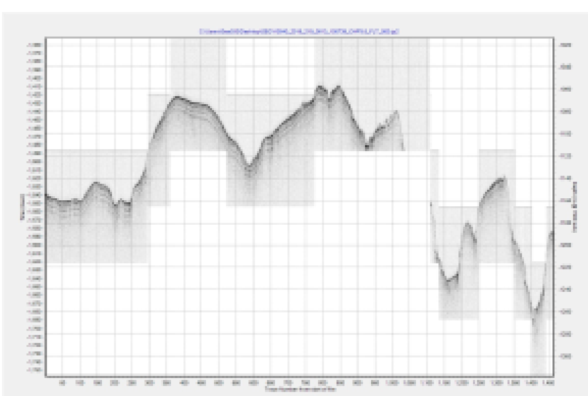

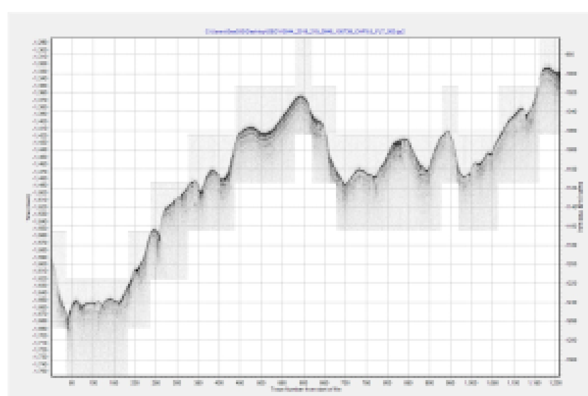

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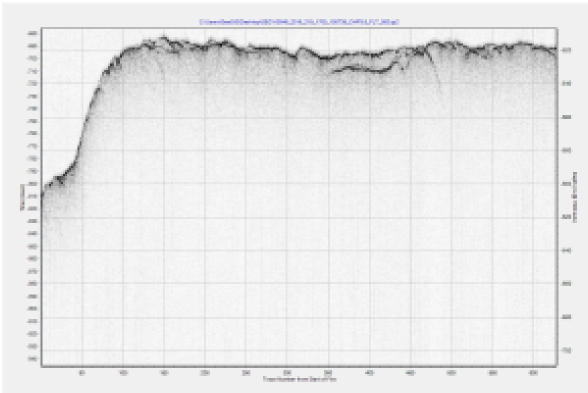

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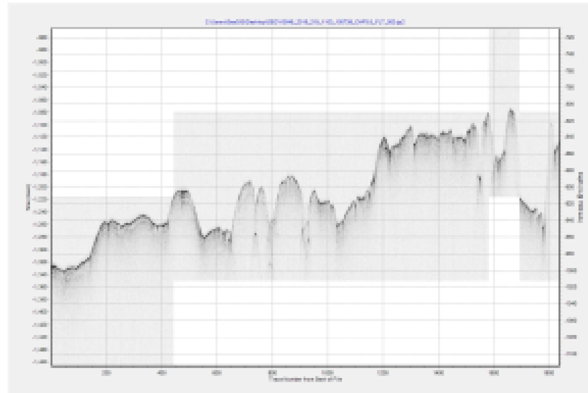

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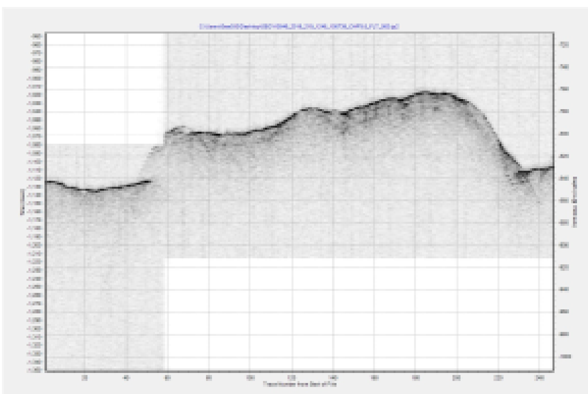

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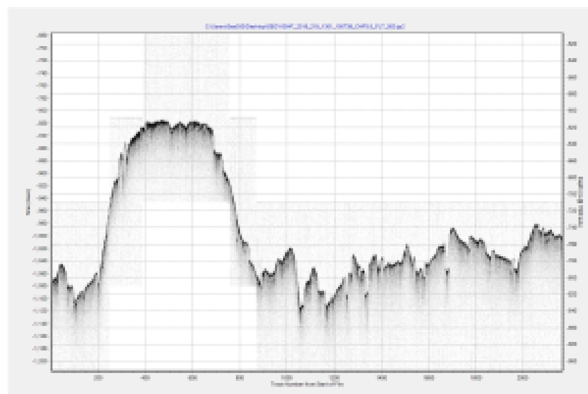

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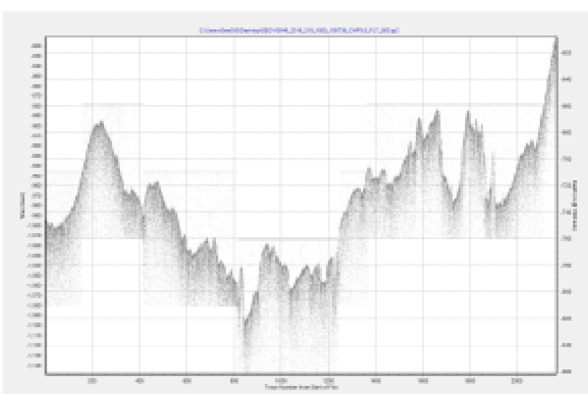

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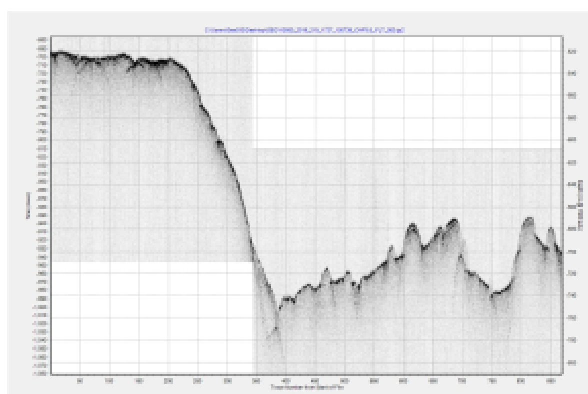

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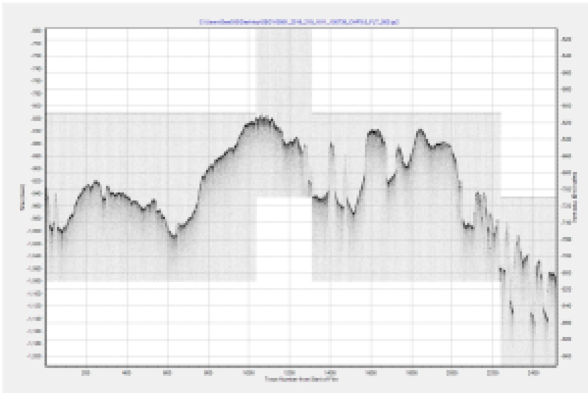

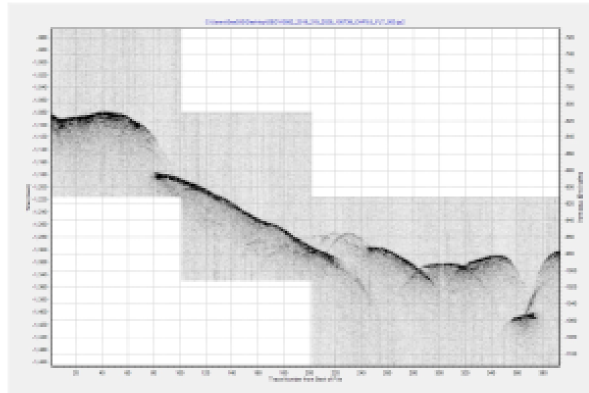

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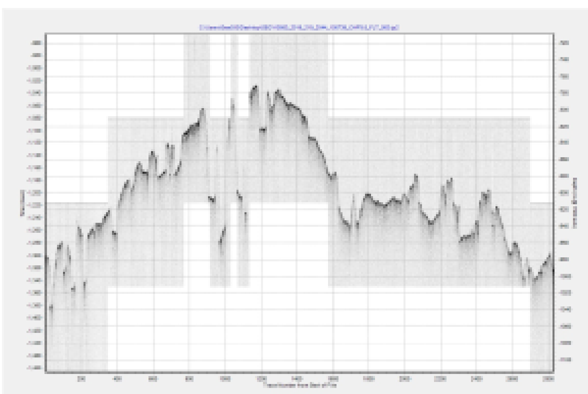

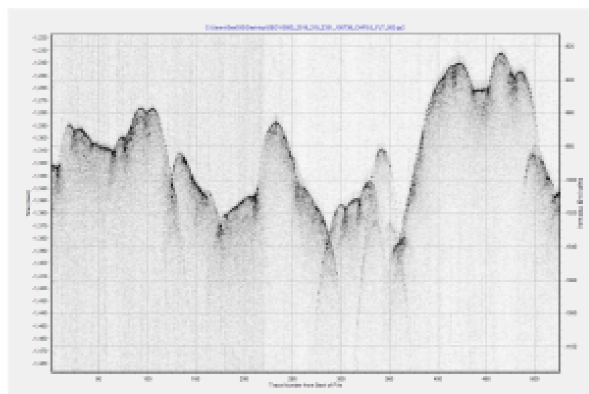

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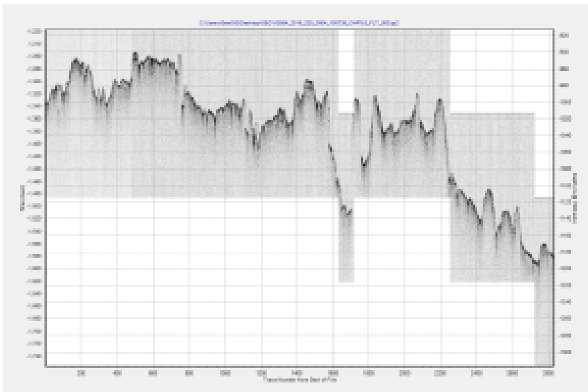
JD220



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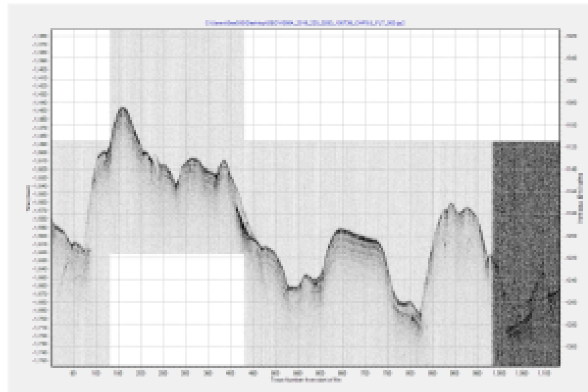

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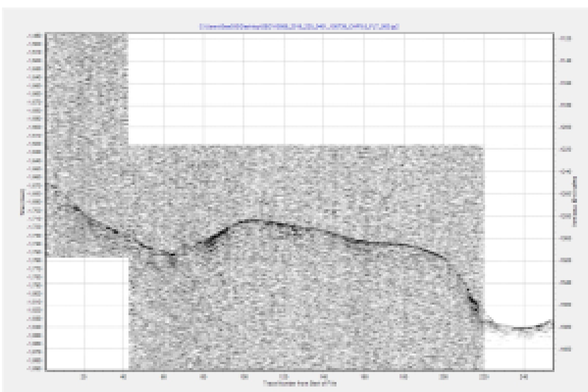

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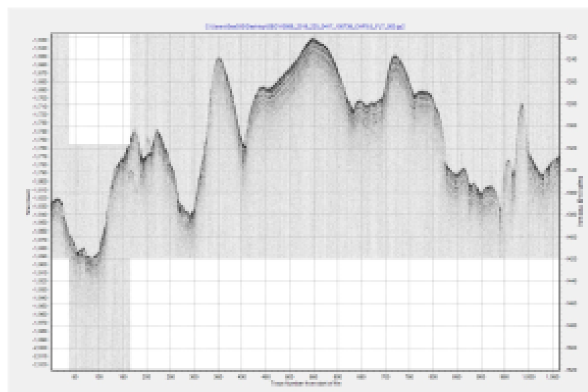

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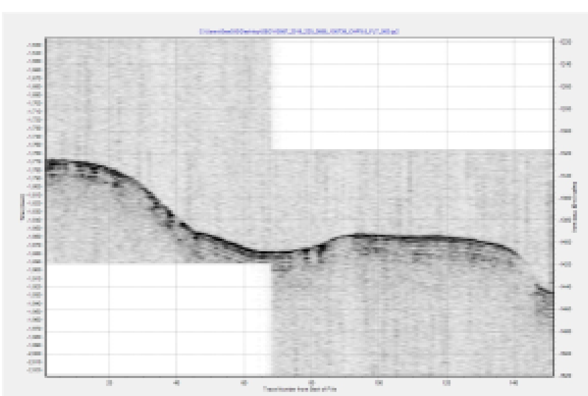

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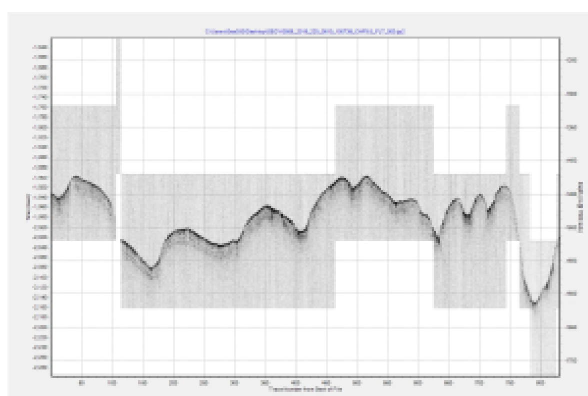

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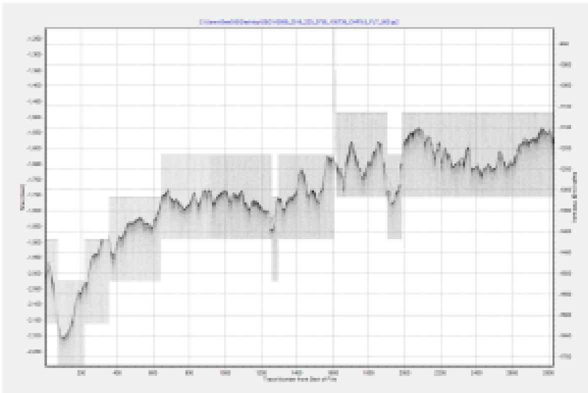

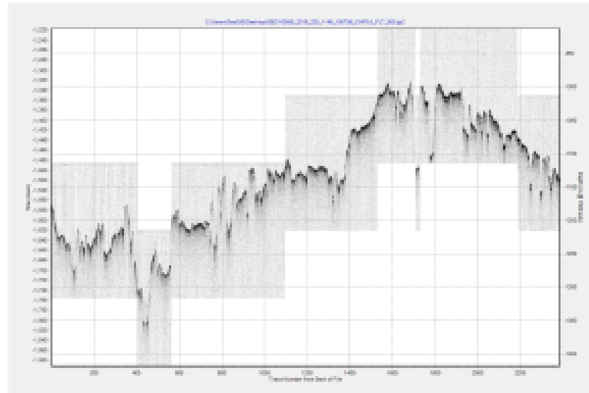

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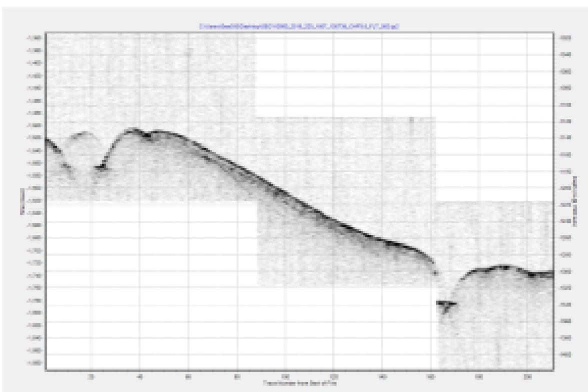

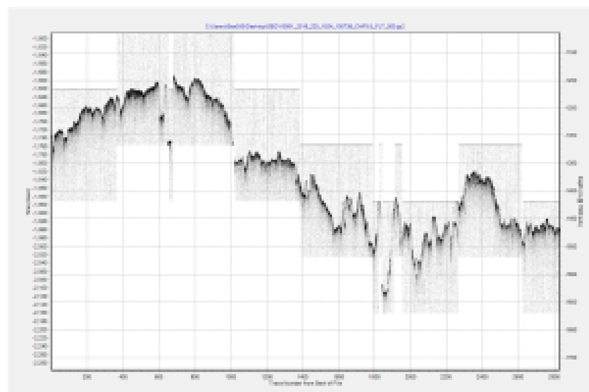

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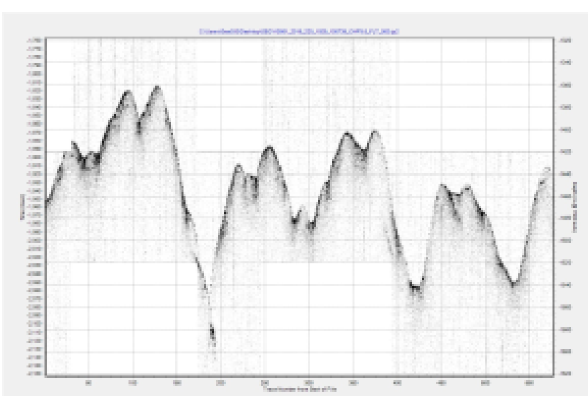

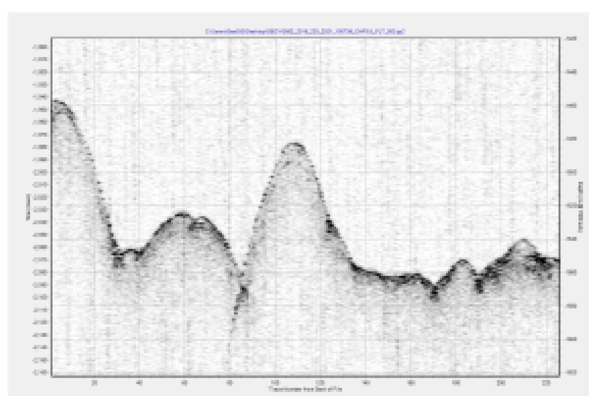

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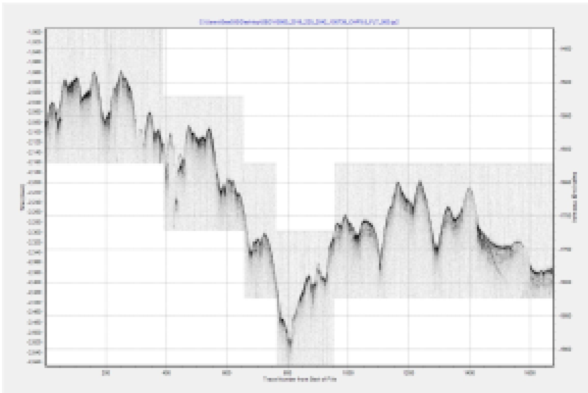

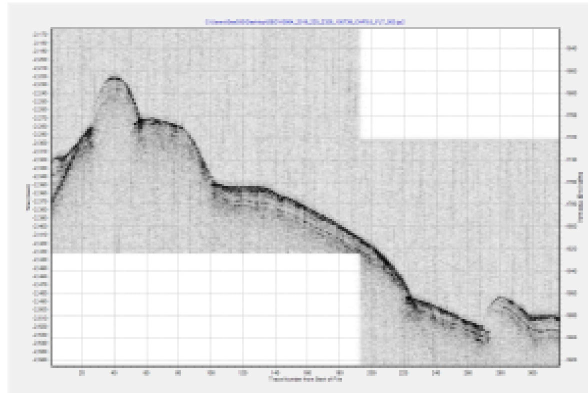

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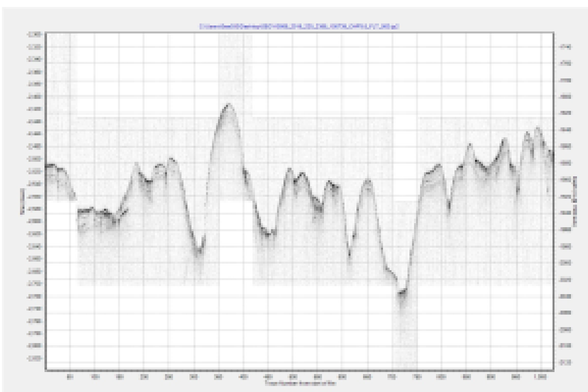

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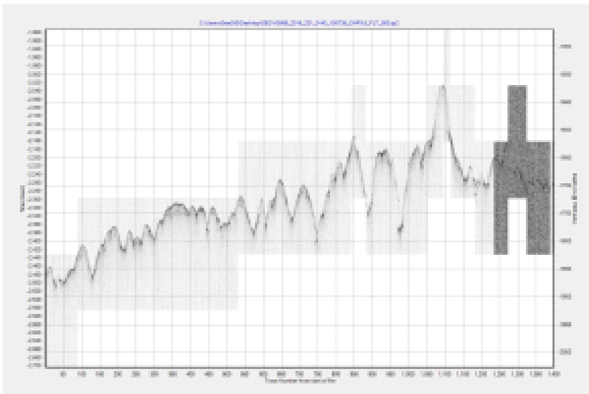
JD221



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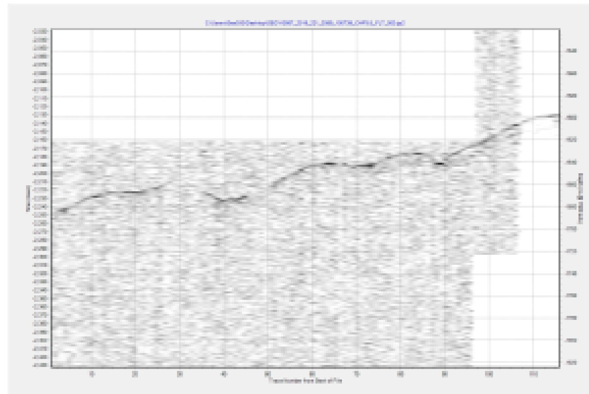

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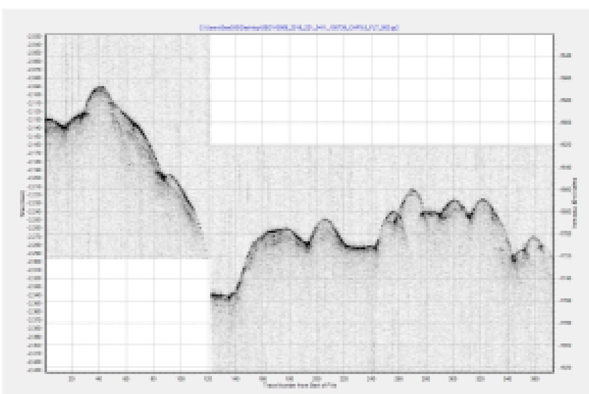

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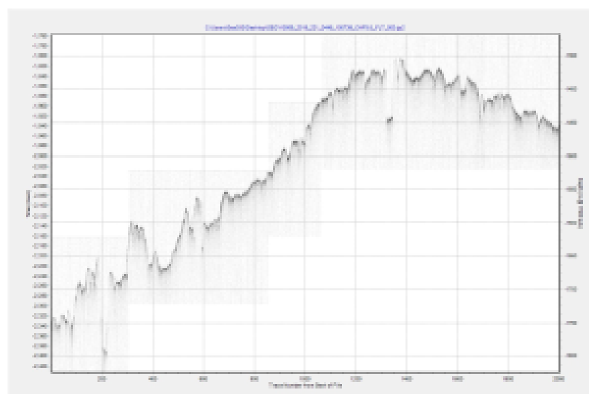

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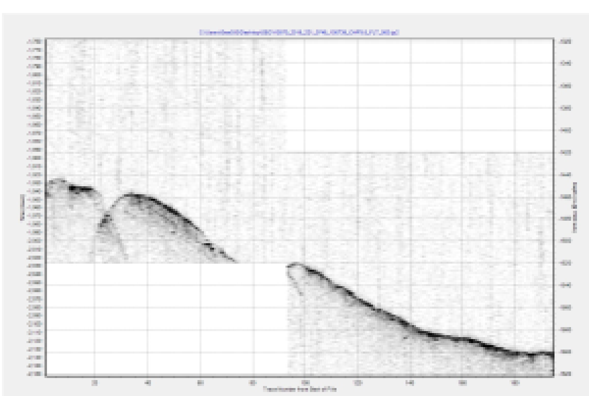

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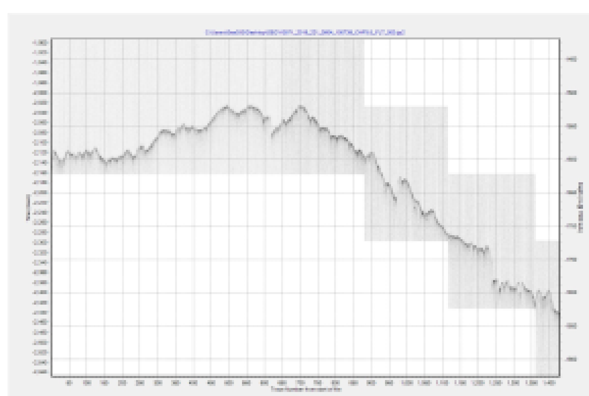

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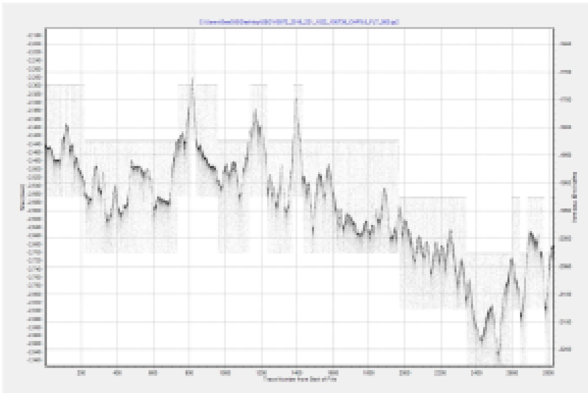

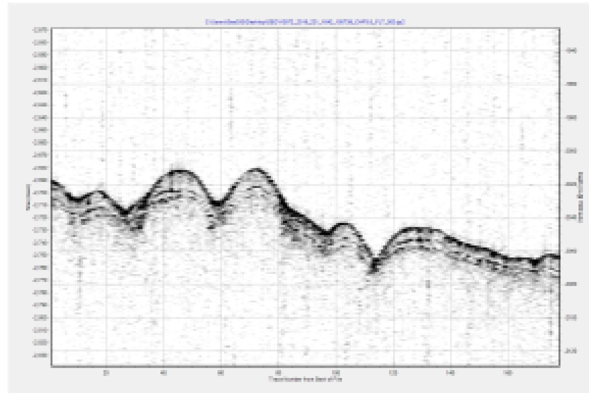

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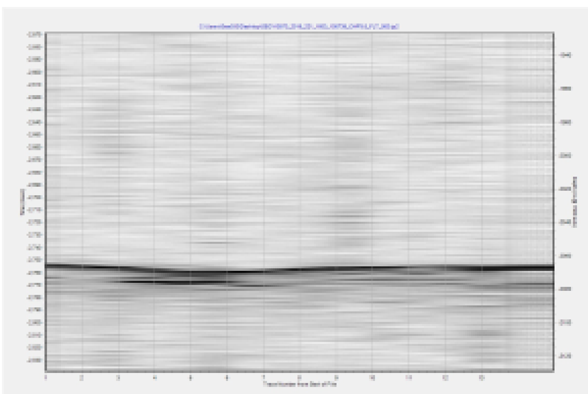

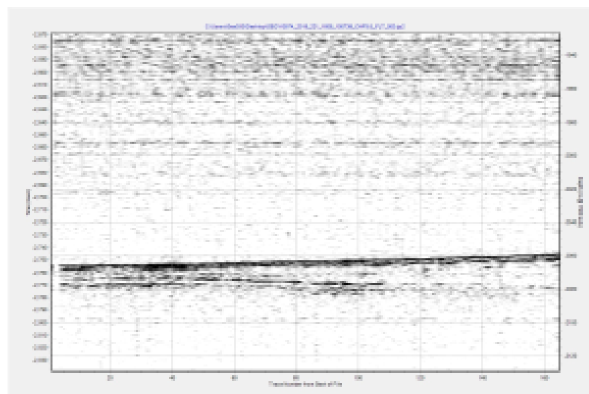

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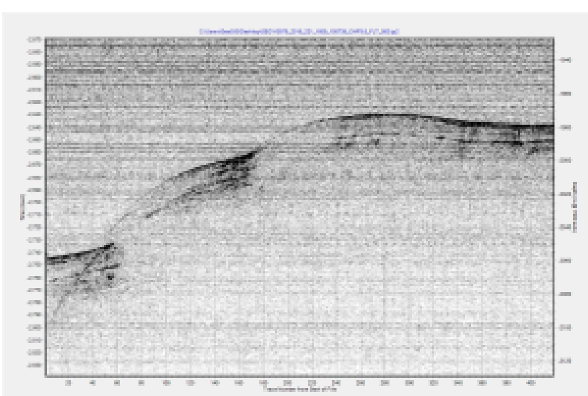

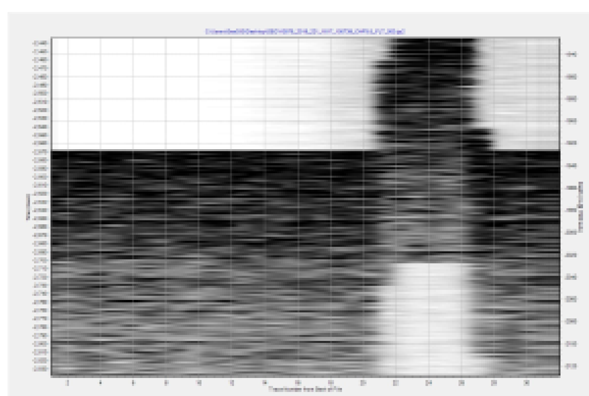

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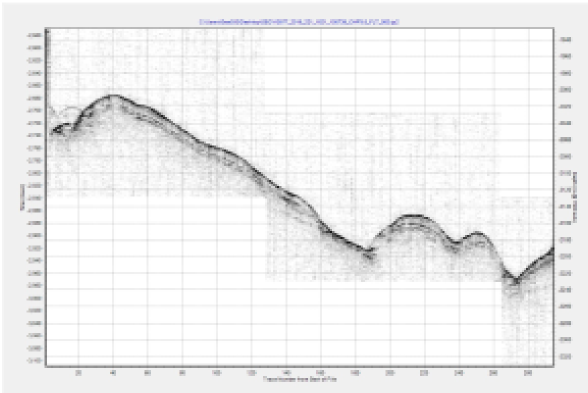

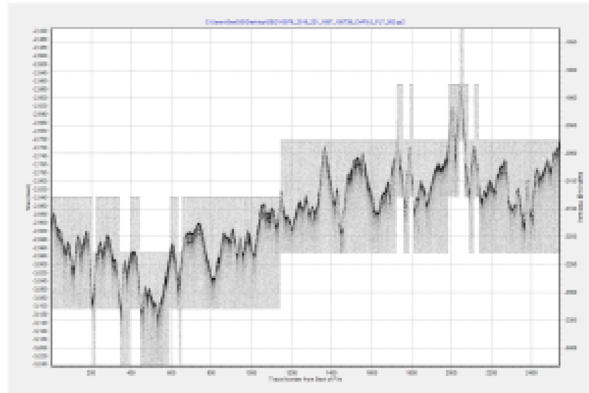

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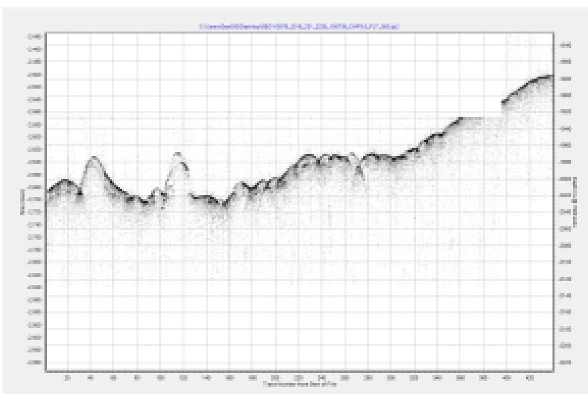

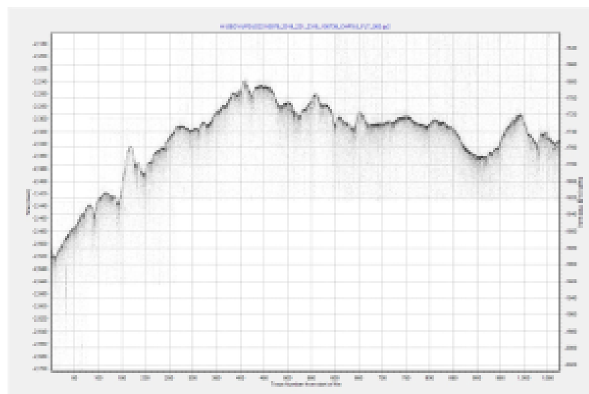

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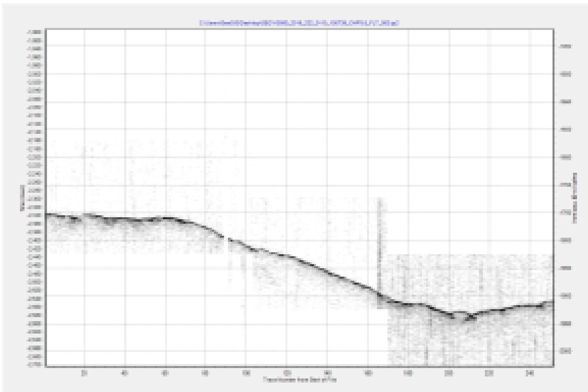
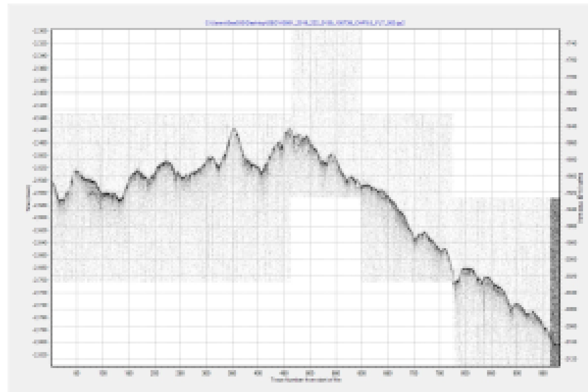
JD222





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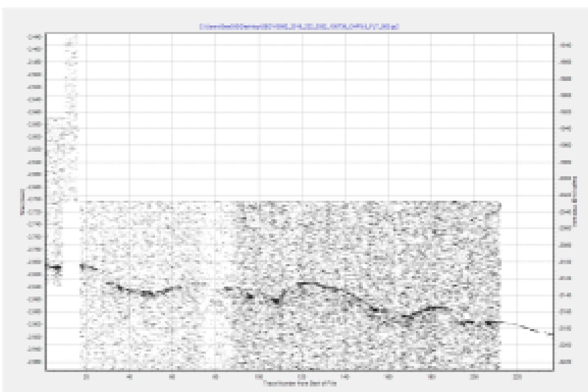

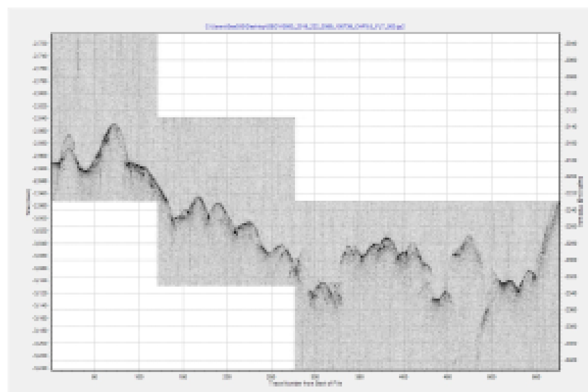

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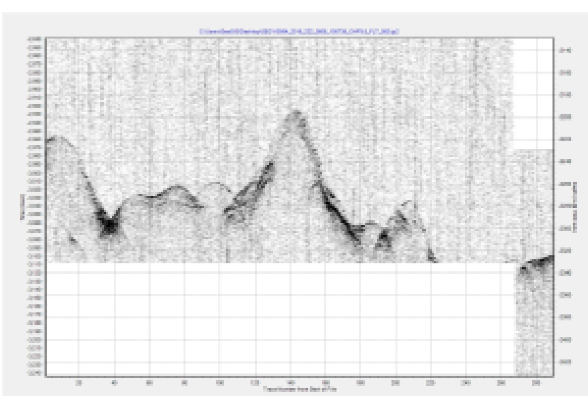

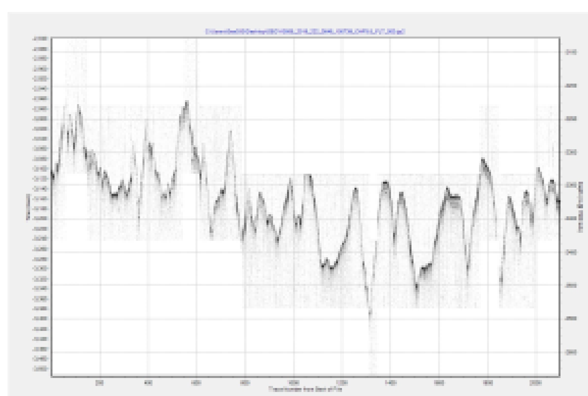

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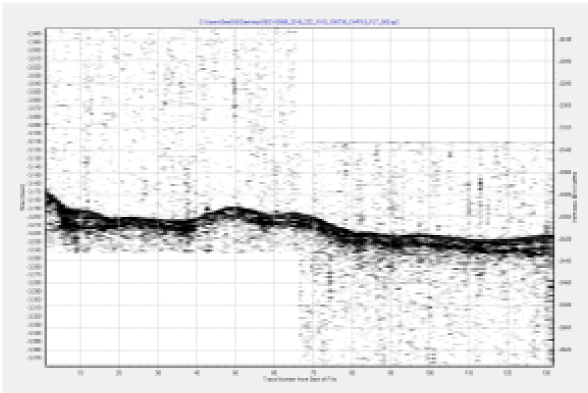

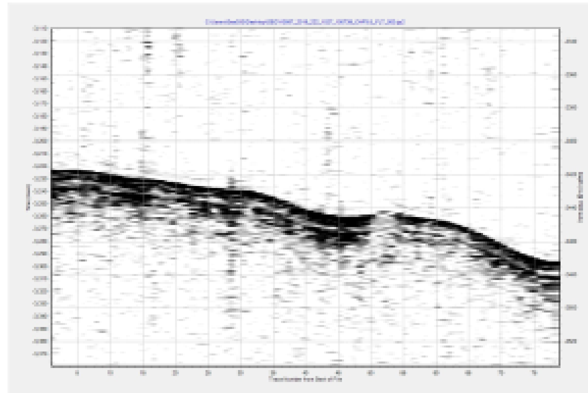

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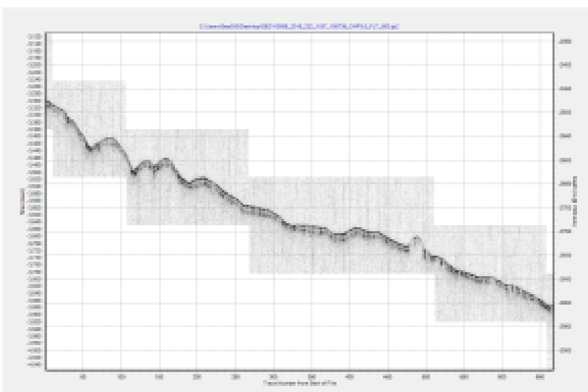

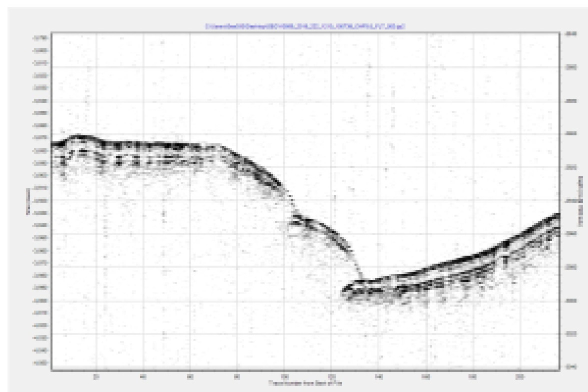

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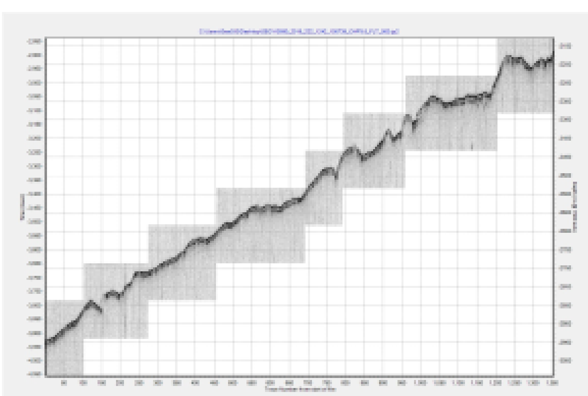

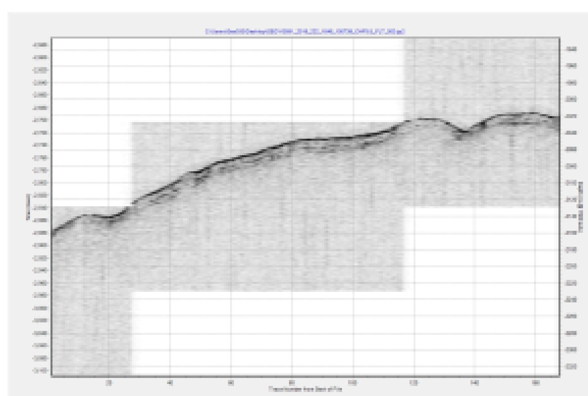

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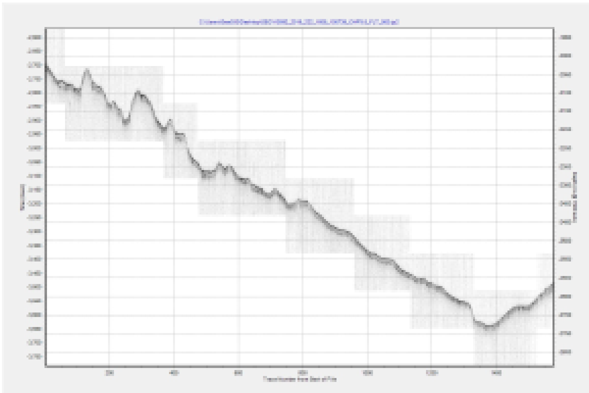

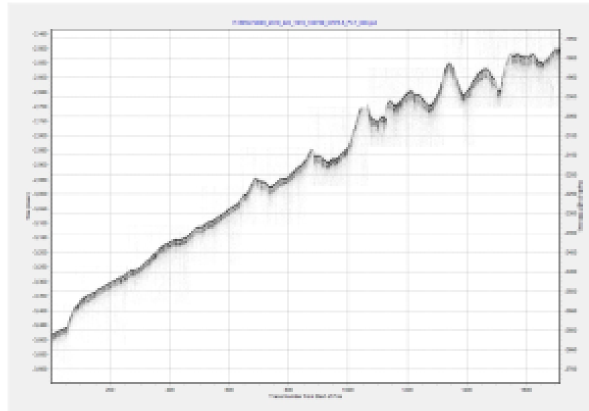

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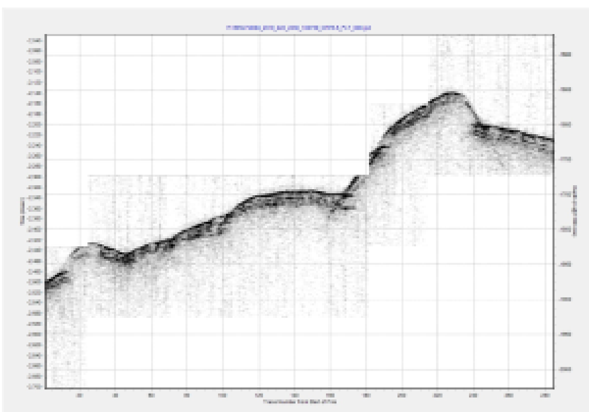

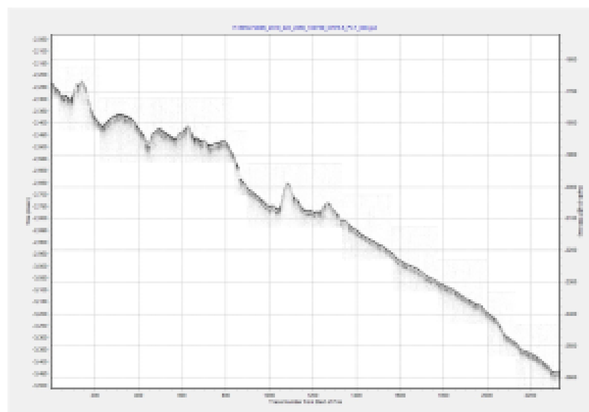

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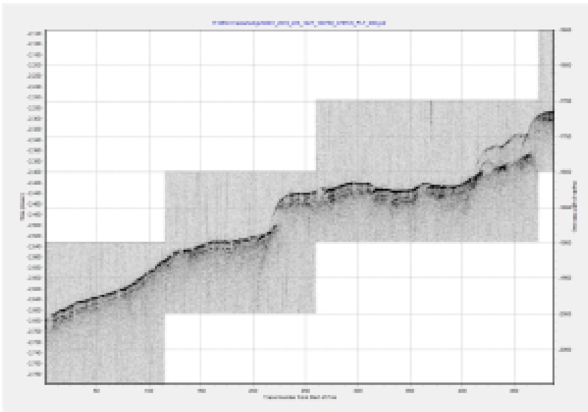
JD223



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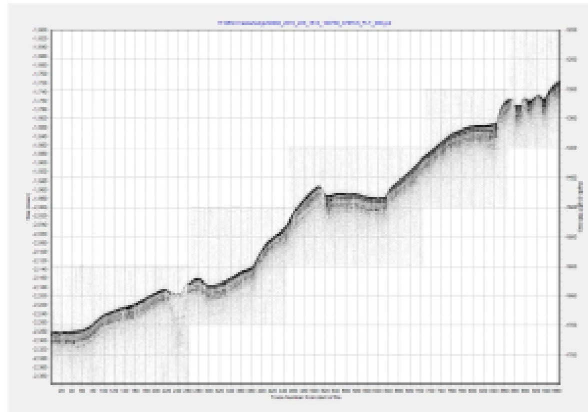

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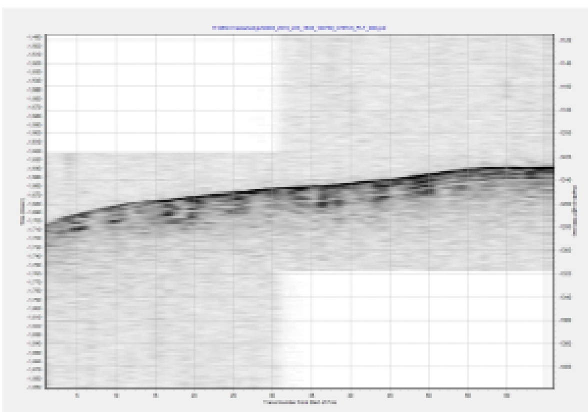

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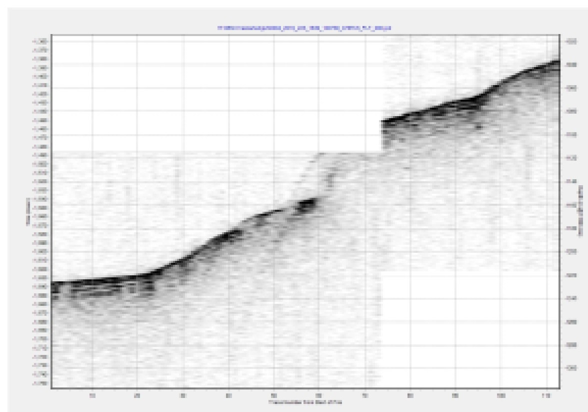

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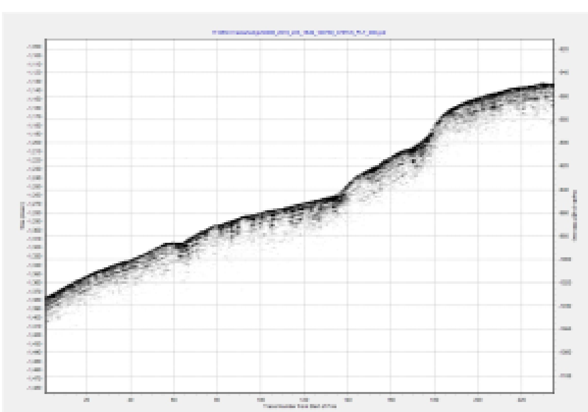

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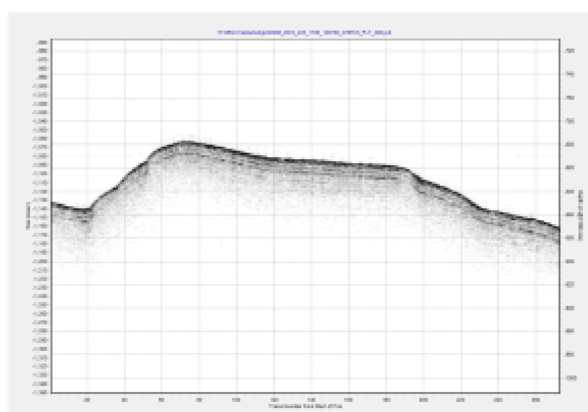

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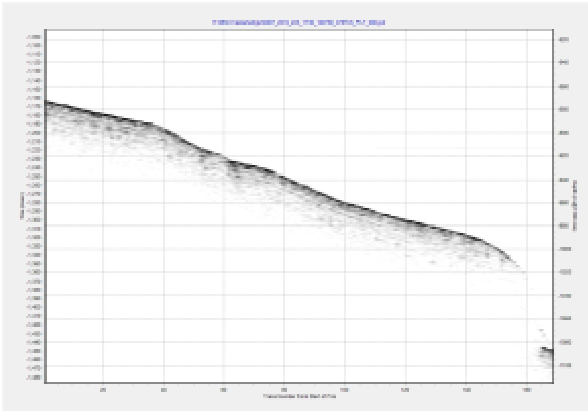

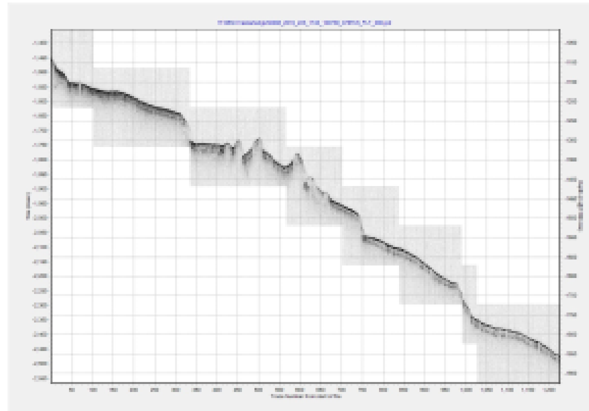

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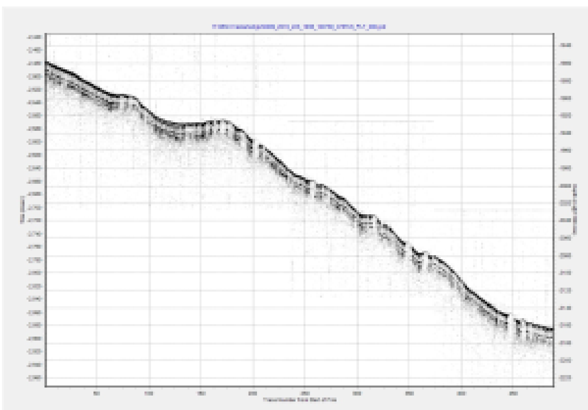

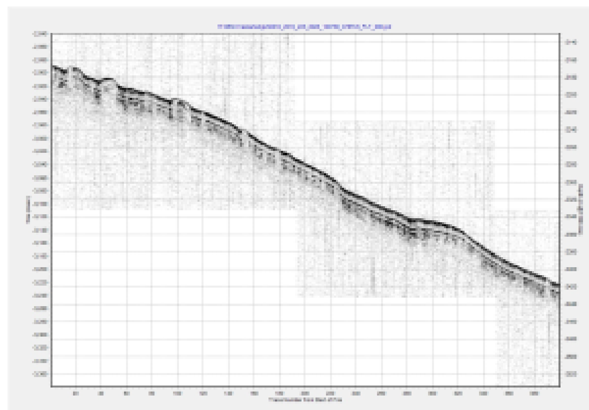

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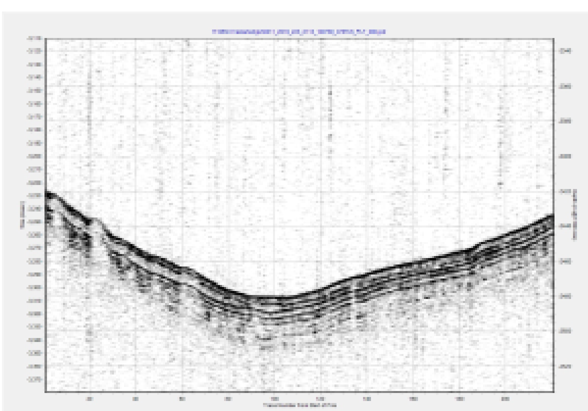

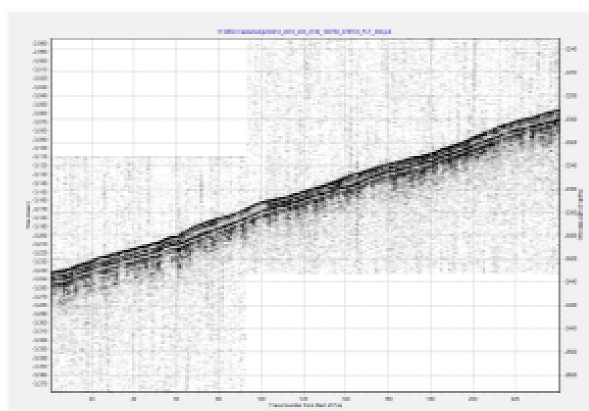

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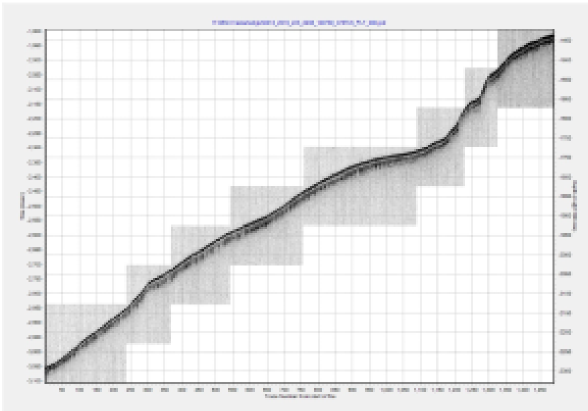

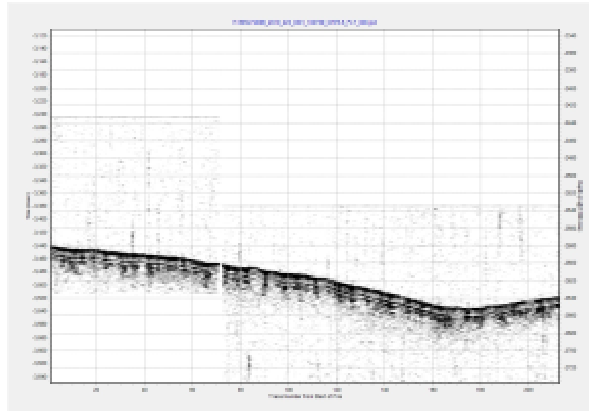

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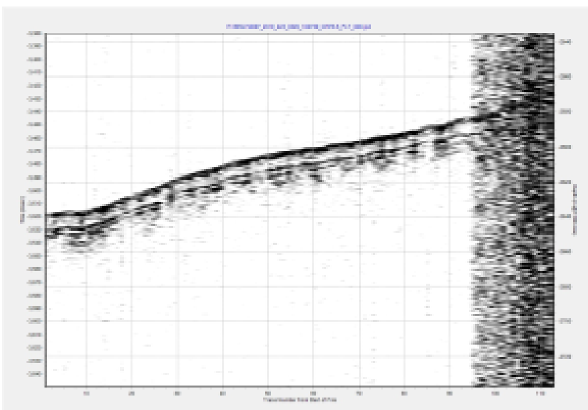

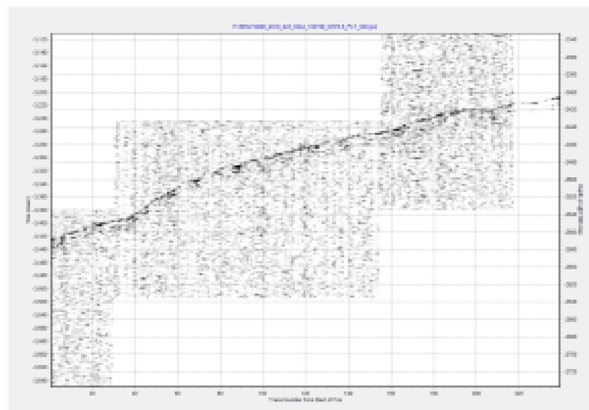

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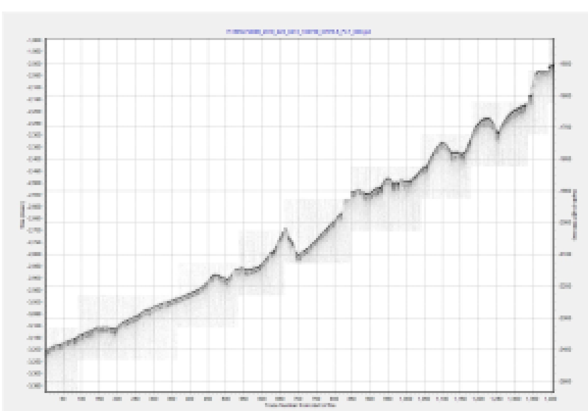

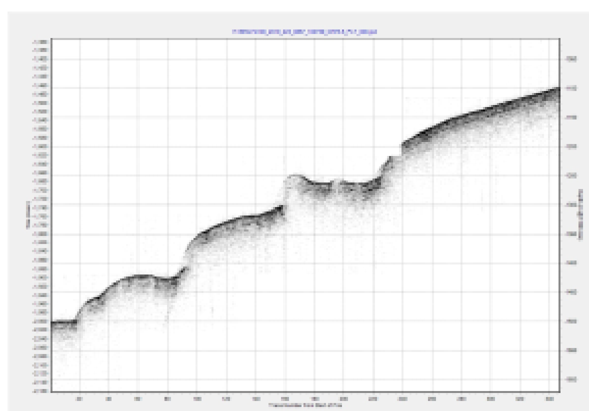

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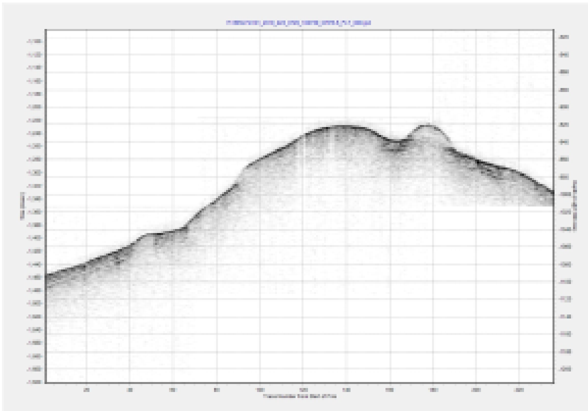

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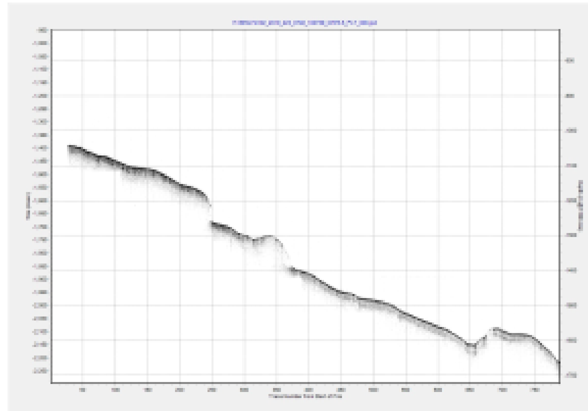

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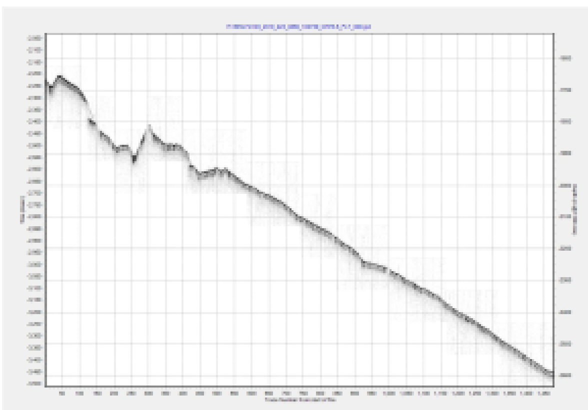

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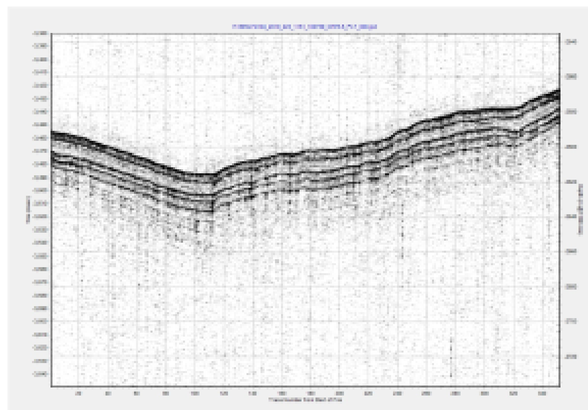

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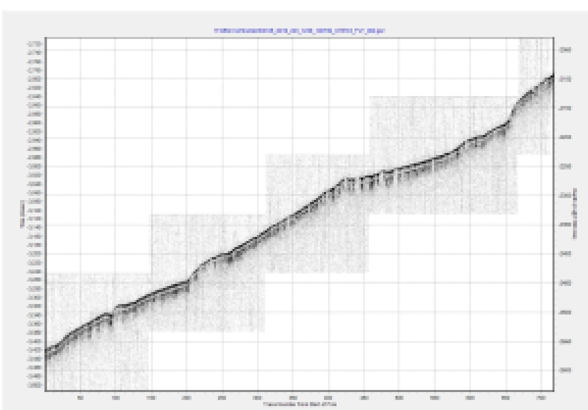

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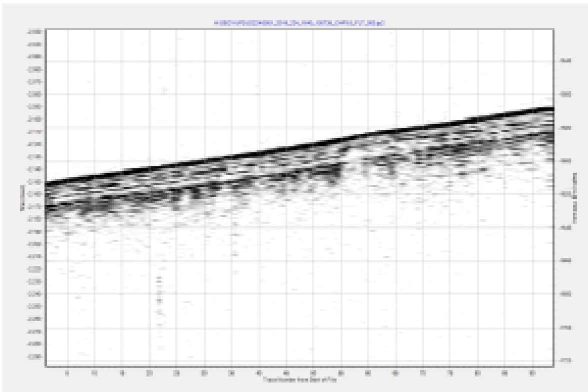
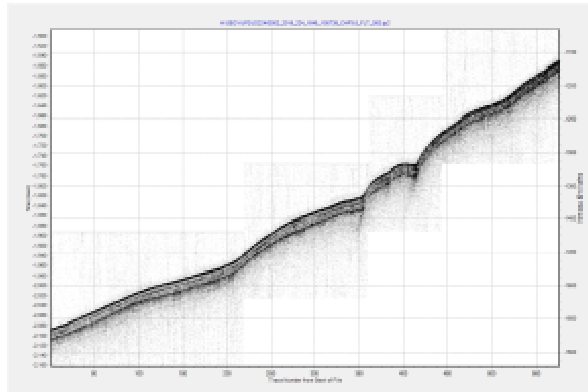
JD224





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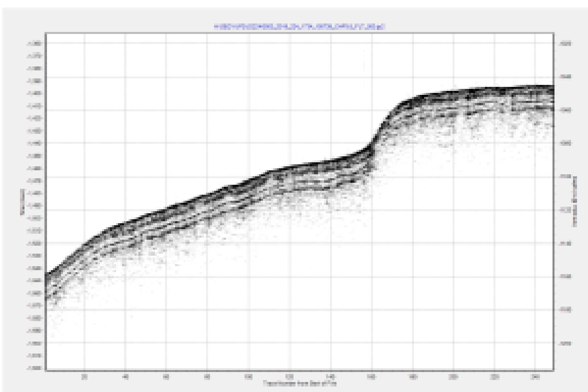

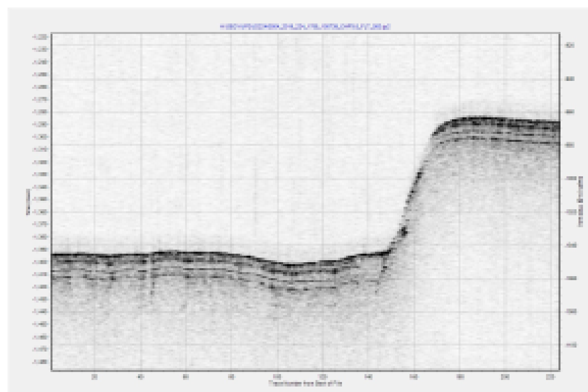

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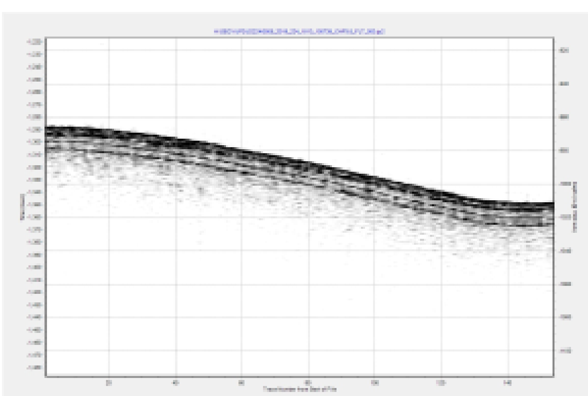

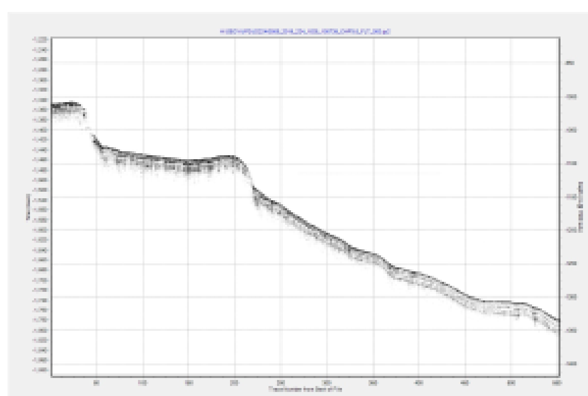

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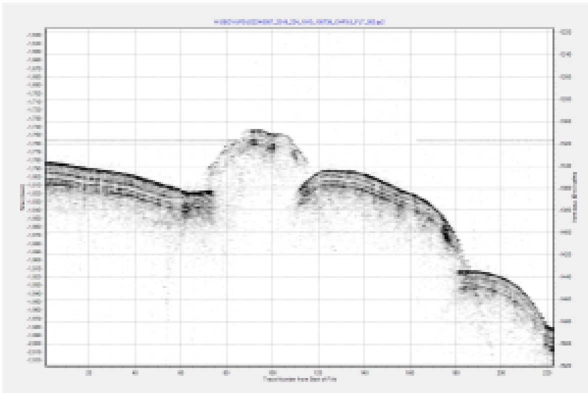

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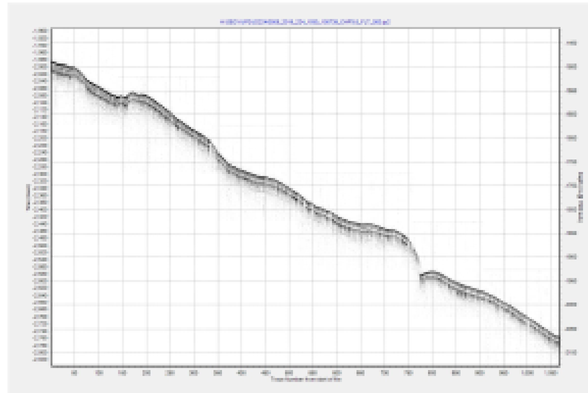

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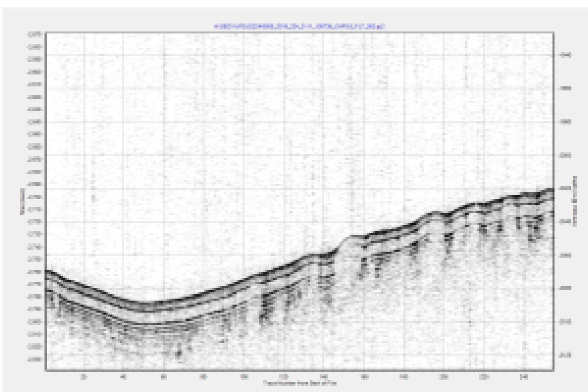

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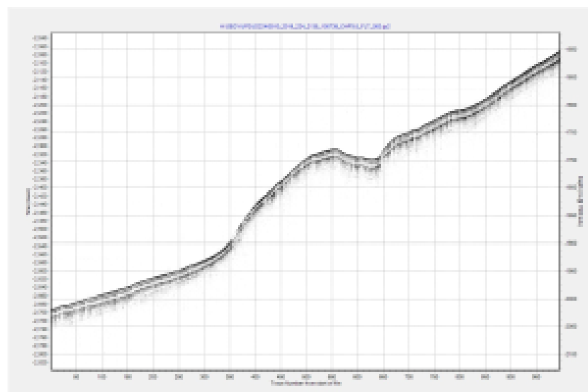

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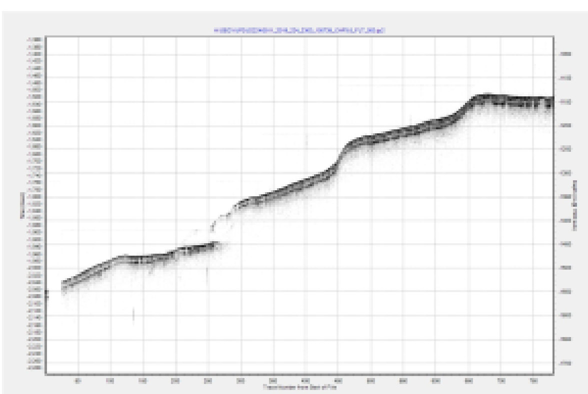

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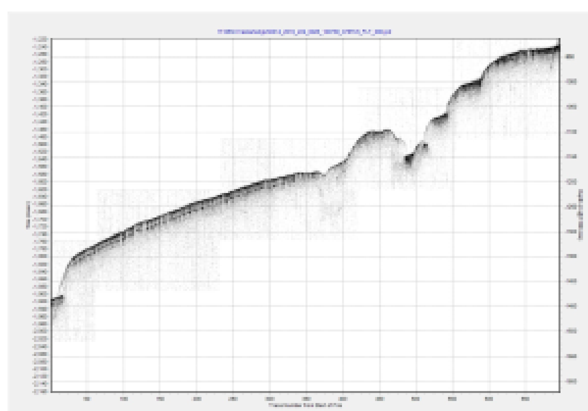

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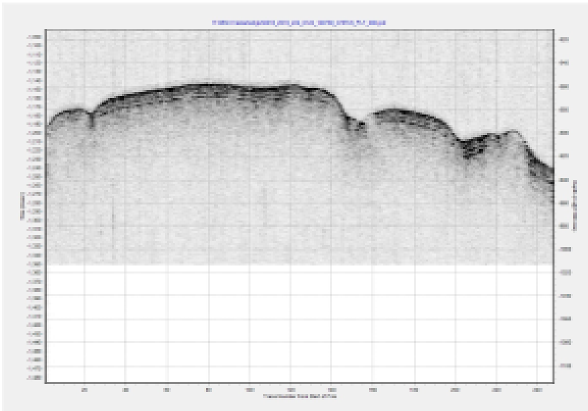

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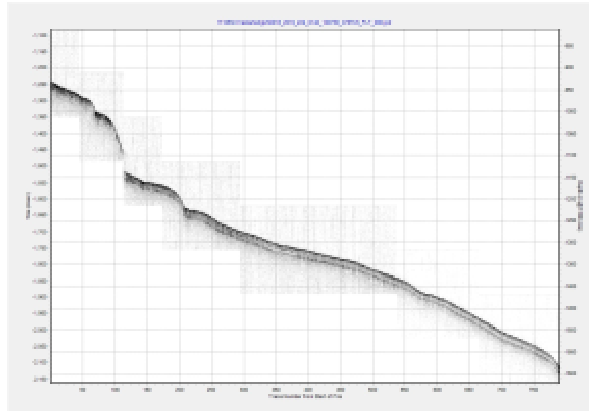

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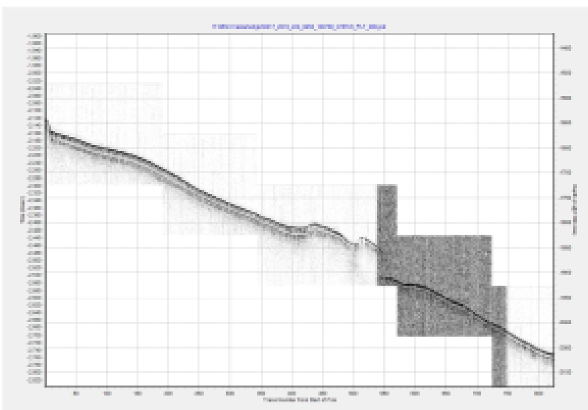

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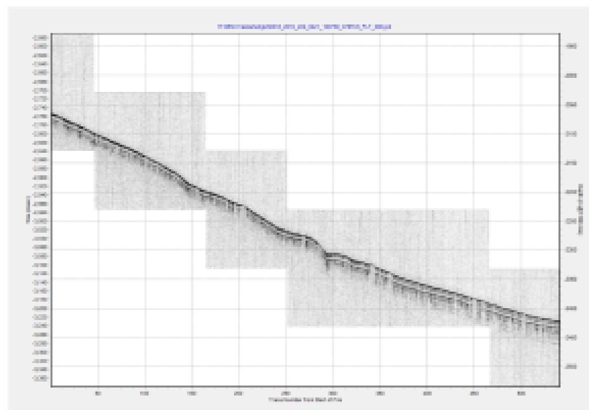

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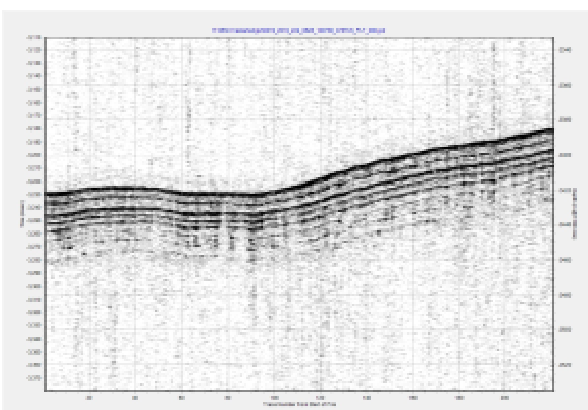

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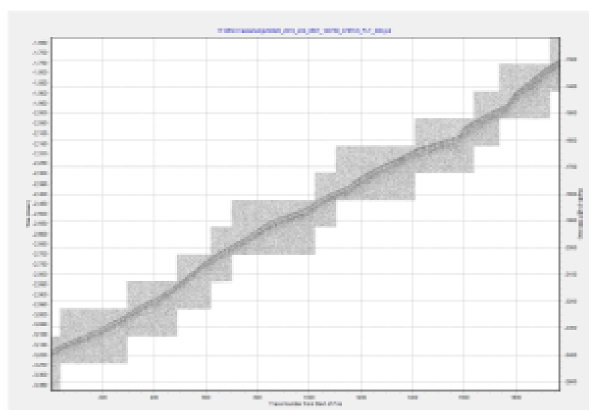

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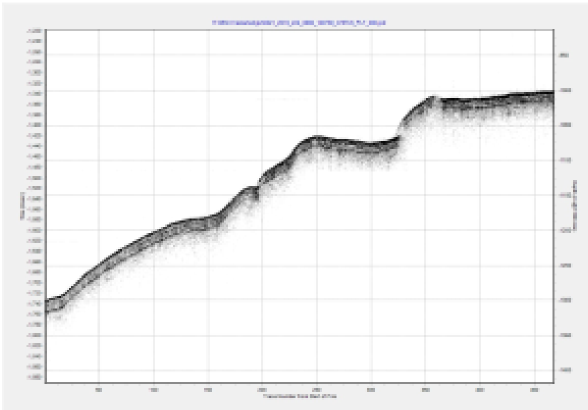

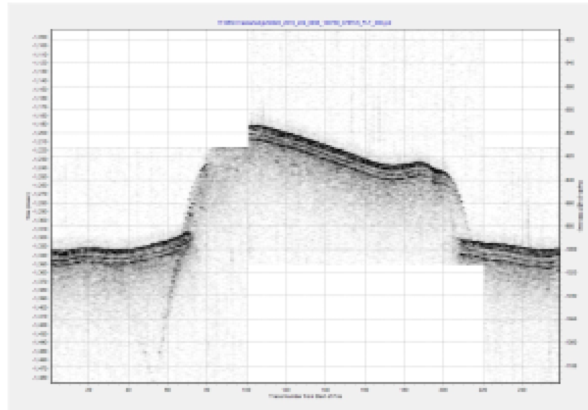

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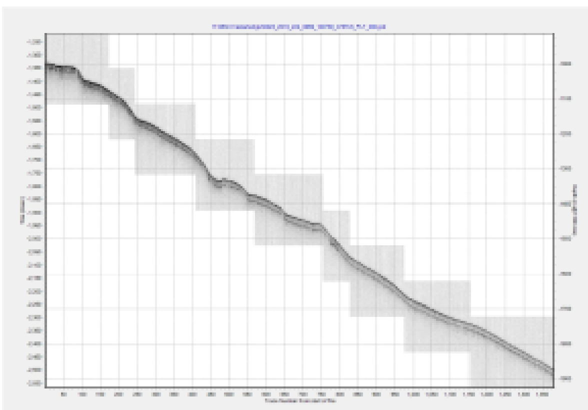

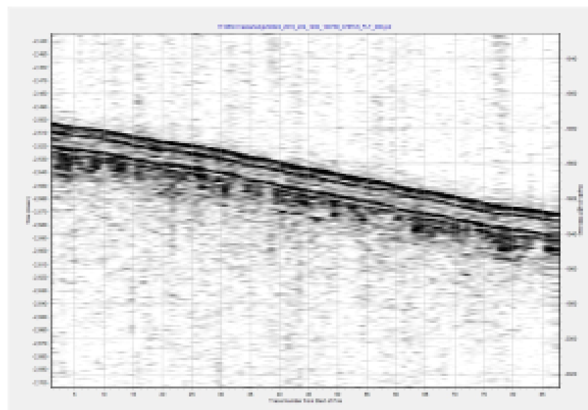

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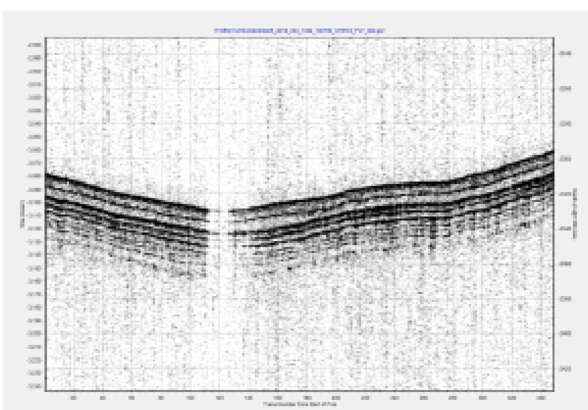

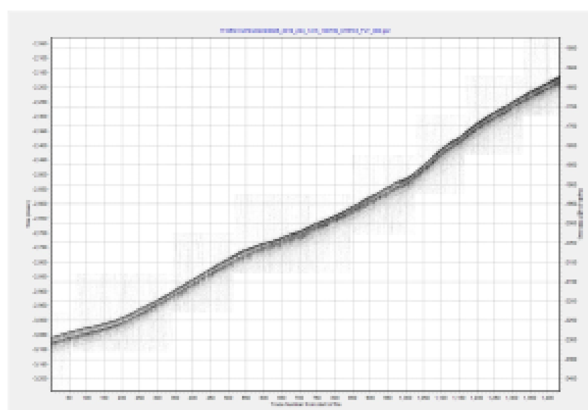

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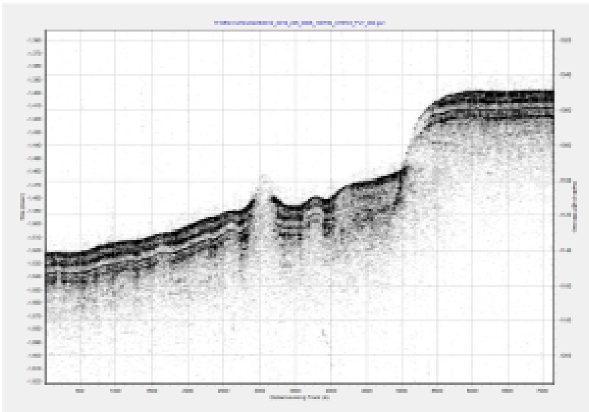

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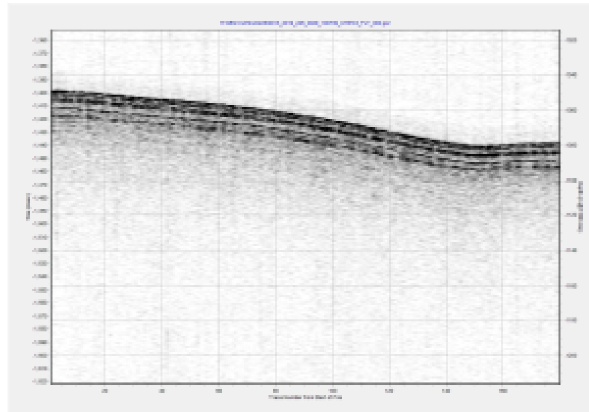

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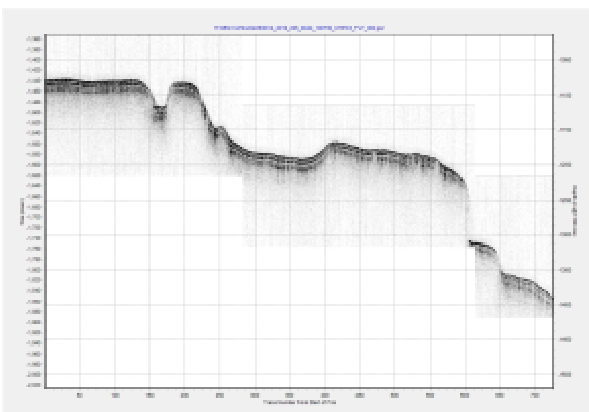

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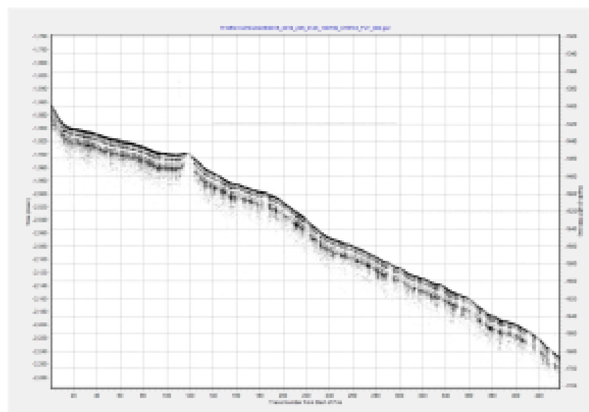

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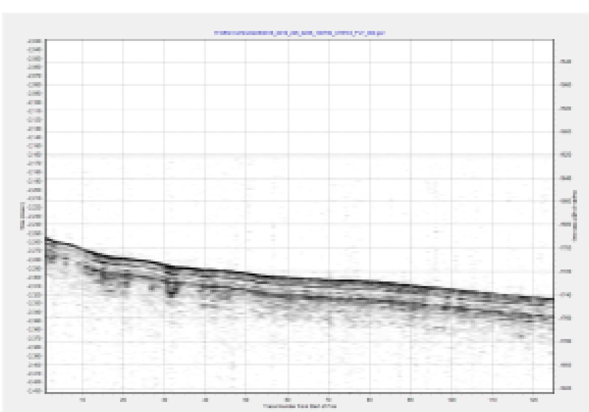

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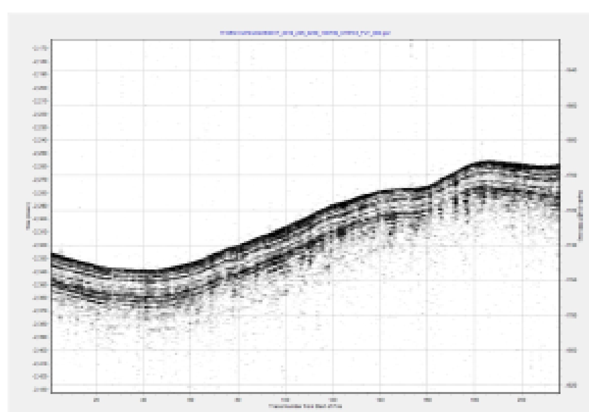

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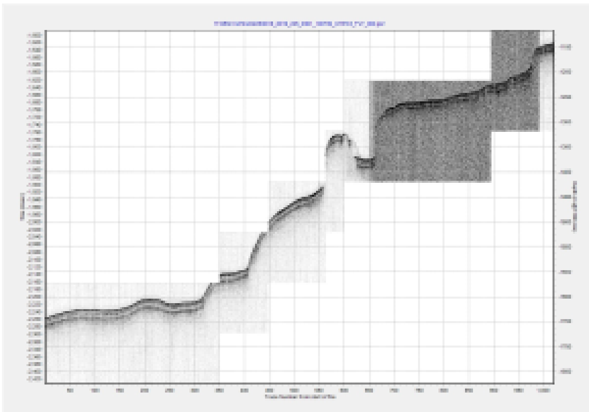

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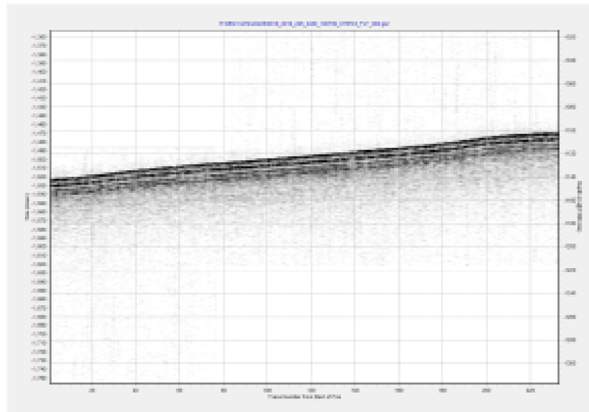

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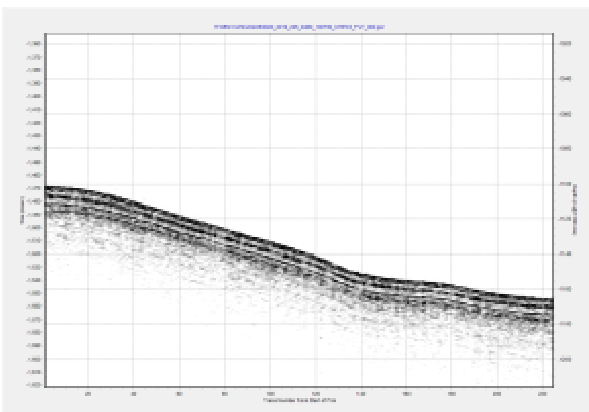

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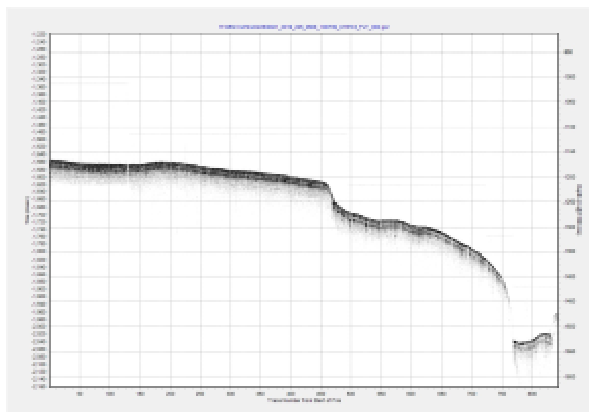

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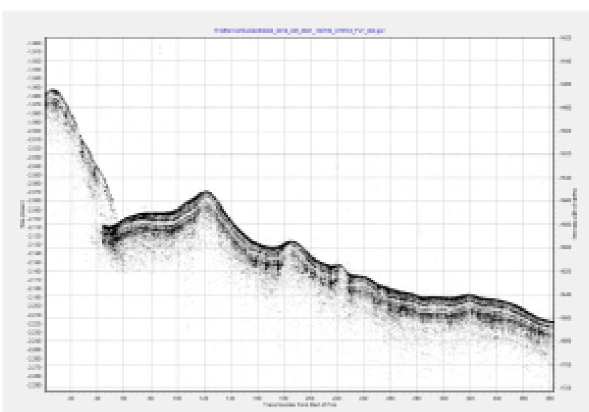

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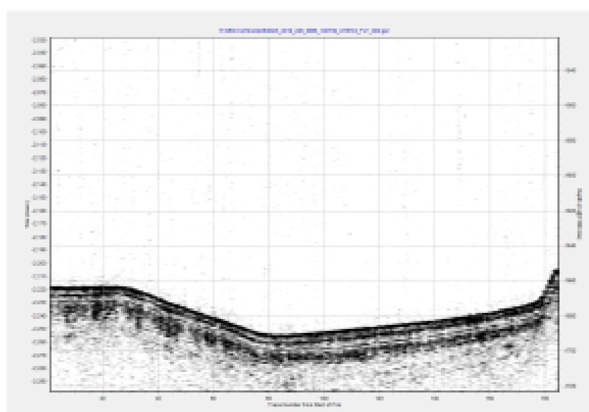

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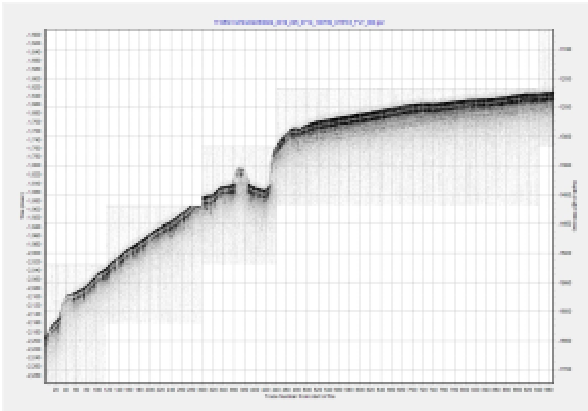

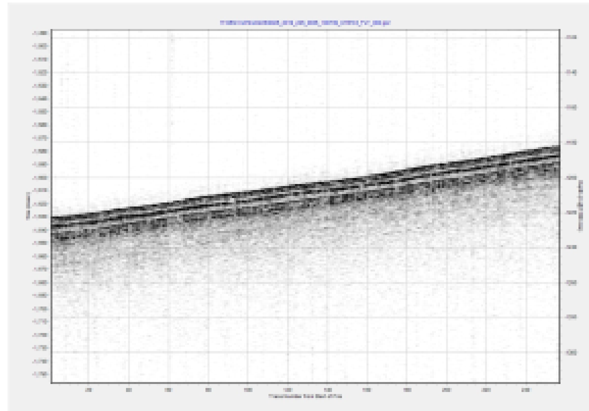

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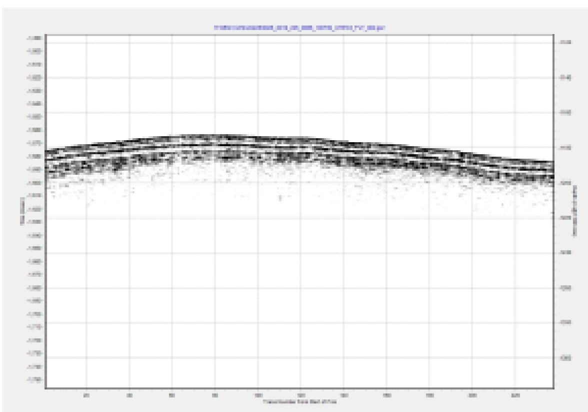

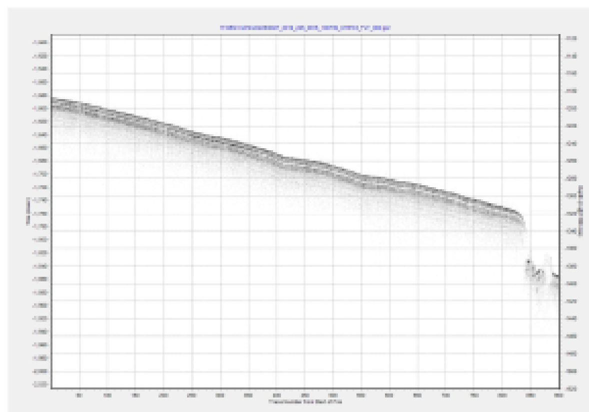

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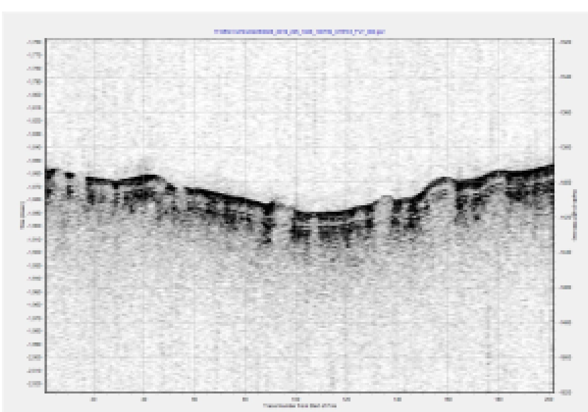

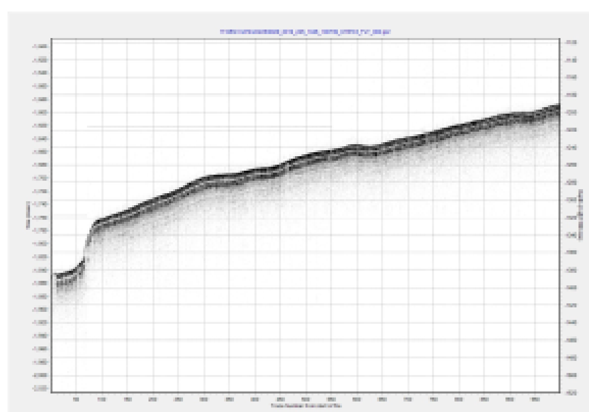

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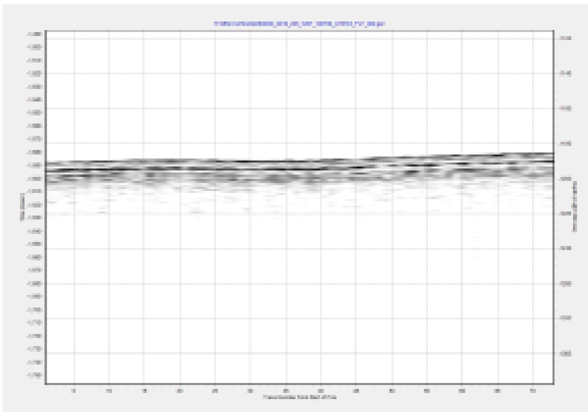

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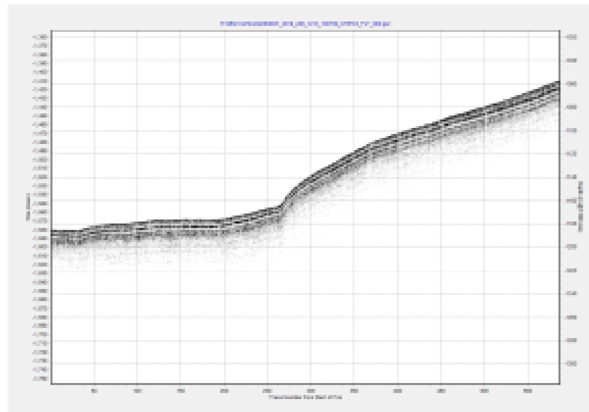

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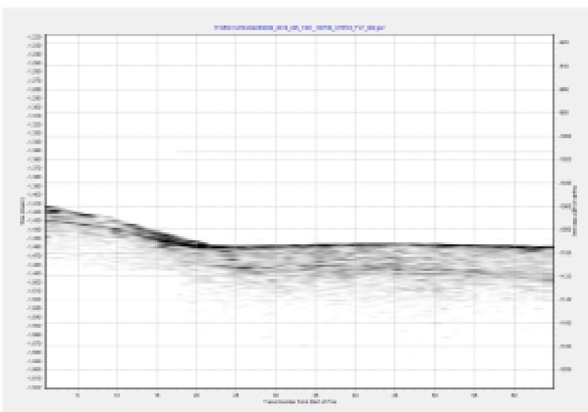

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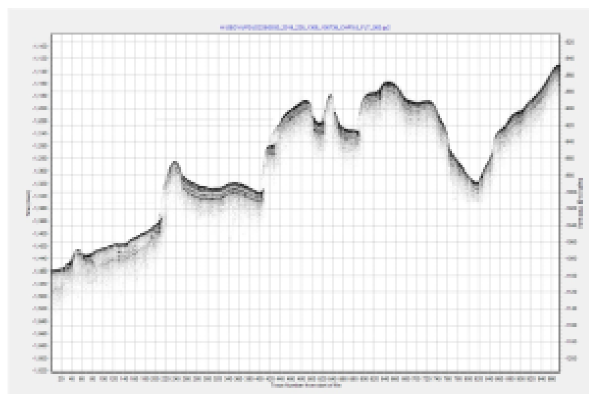

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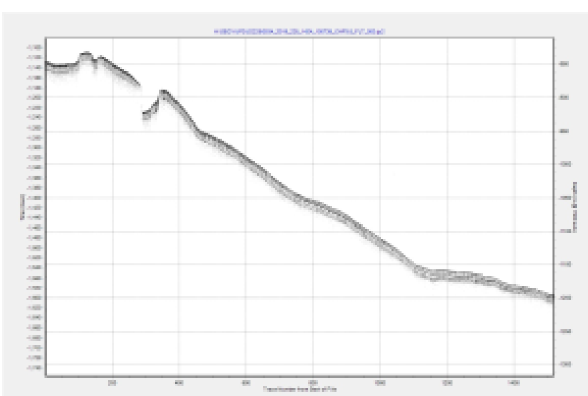

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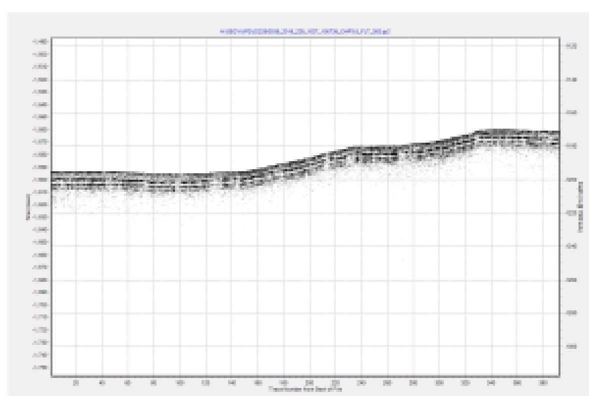

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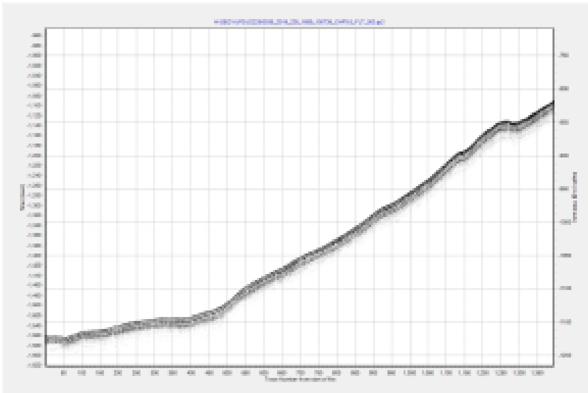

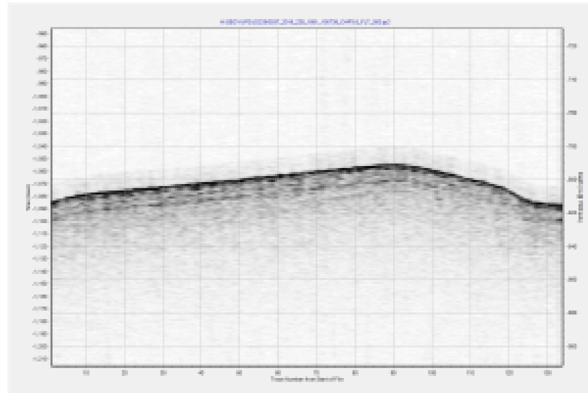

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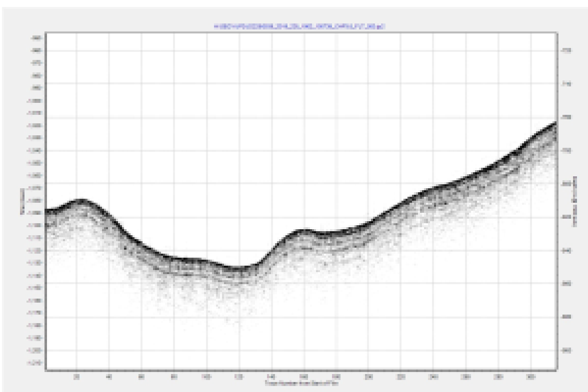

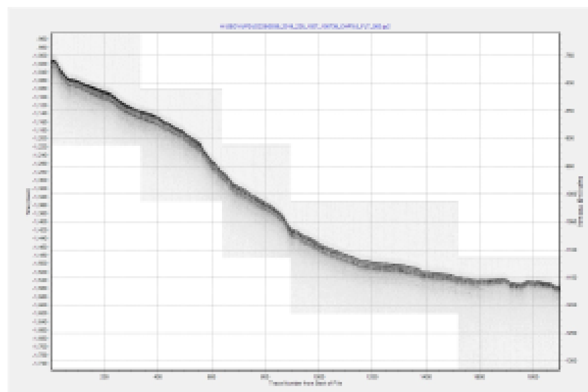

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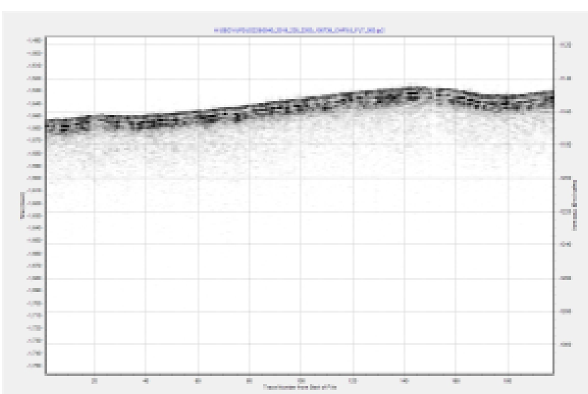

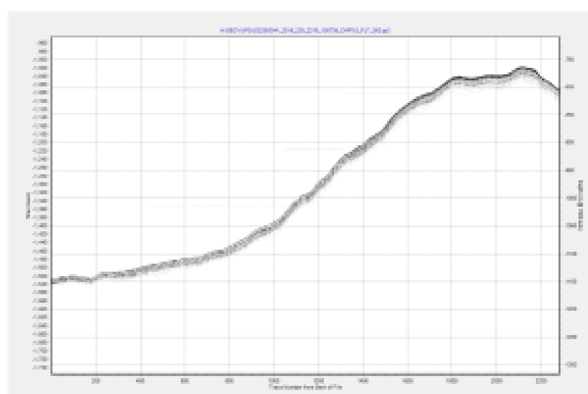

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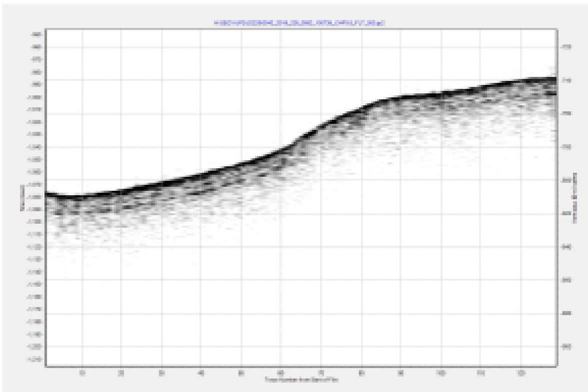

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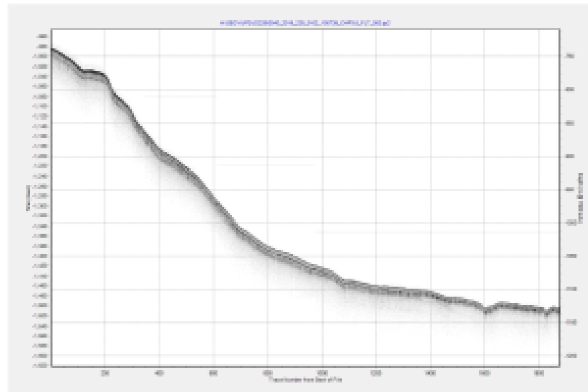

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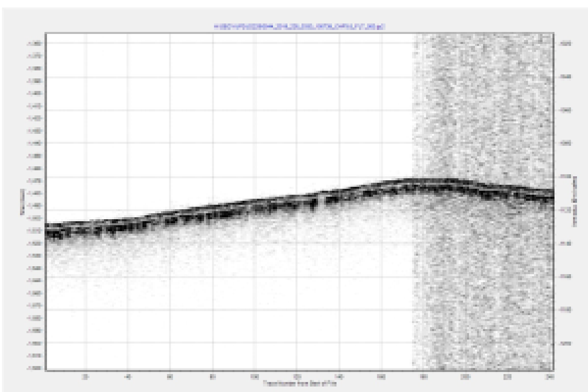

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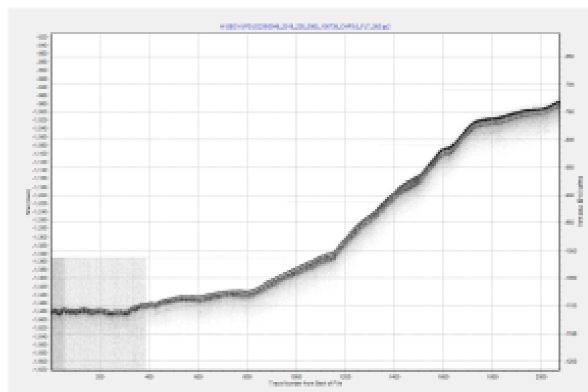

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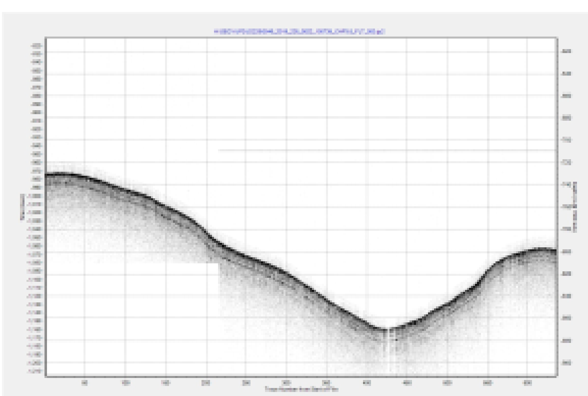

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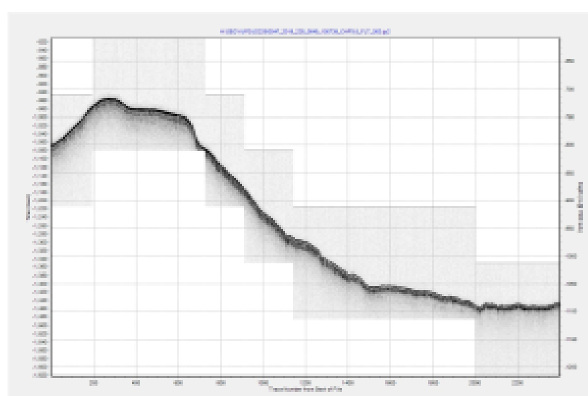

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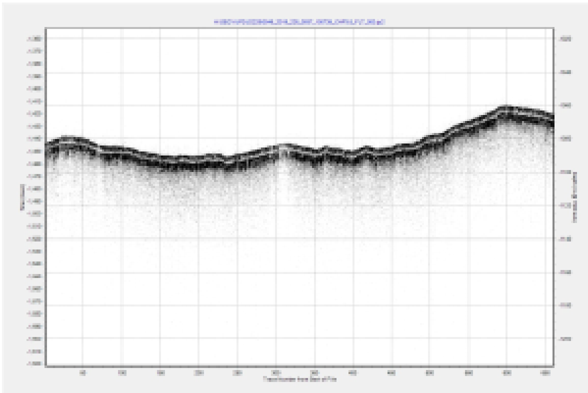

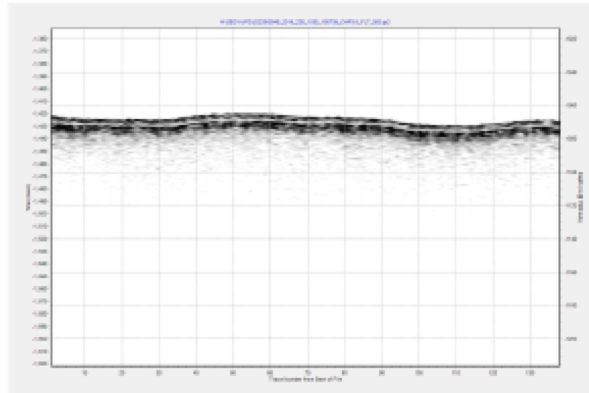

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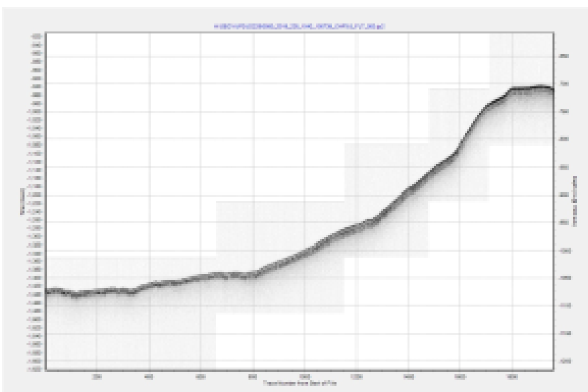

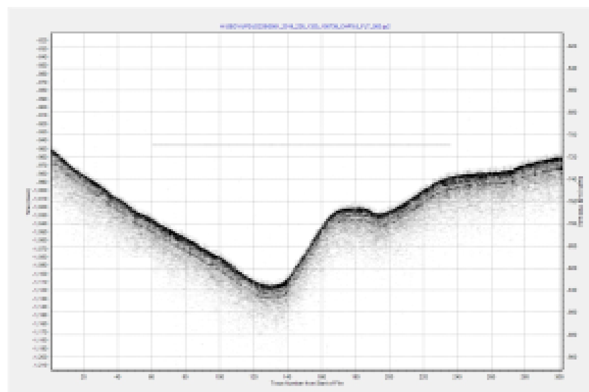

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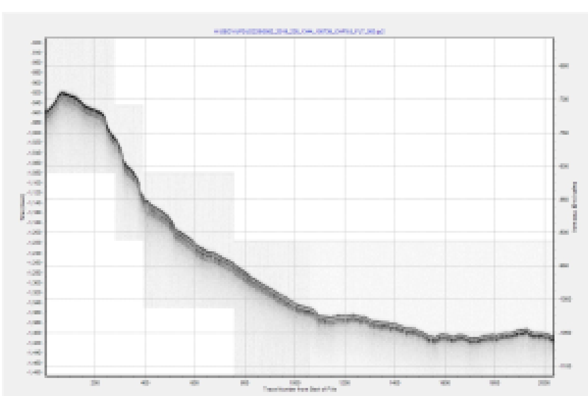

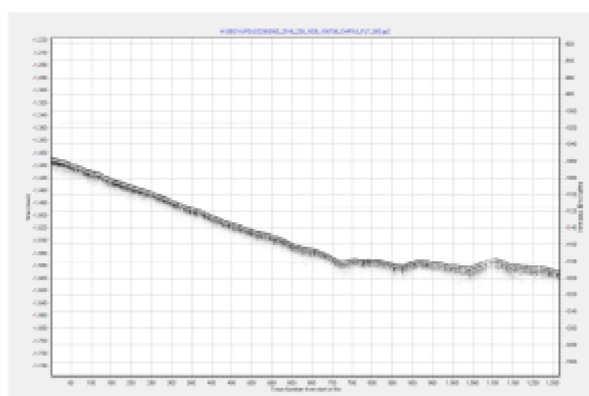

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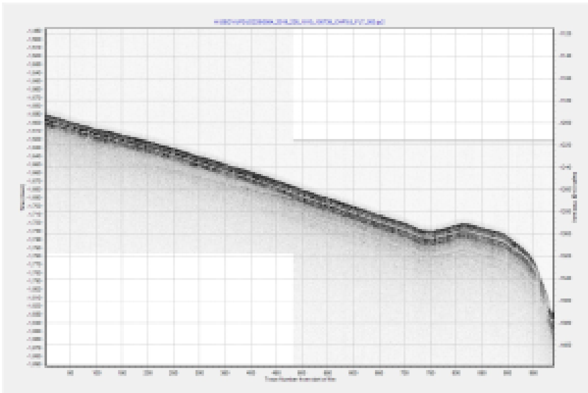

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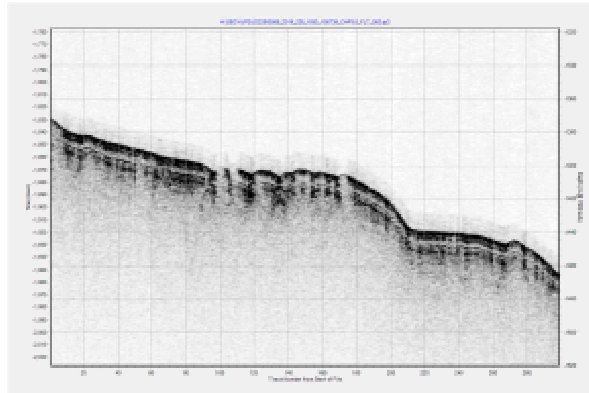

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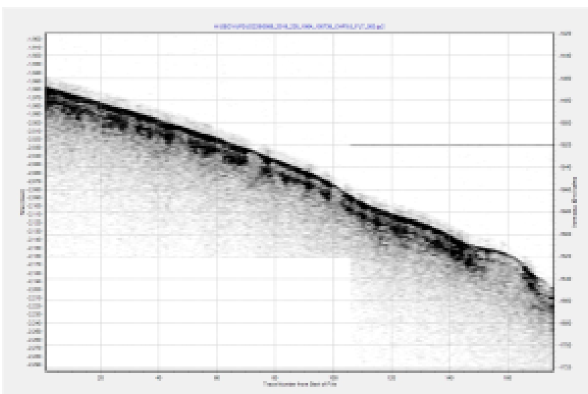

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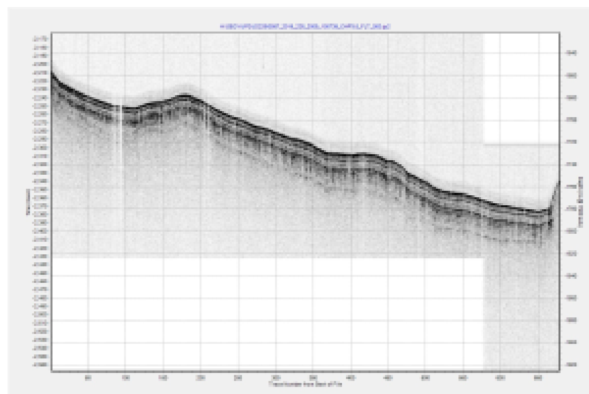

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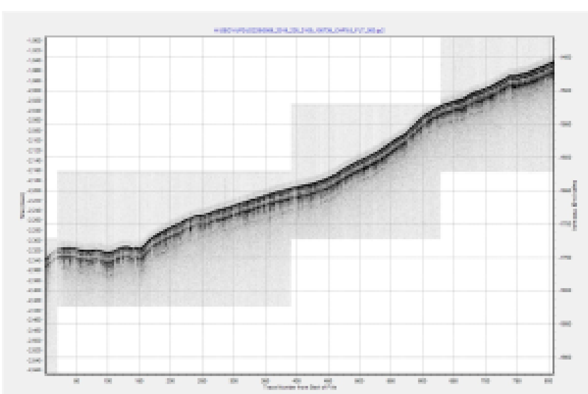

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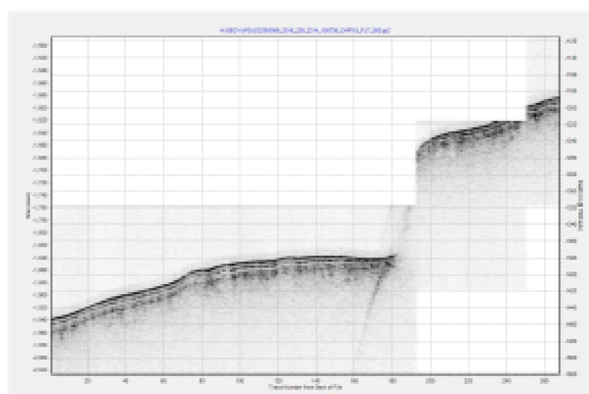

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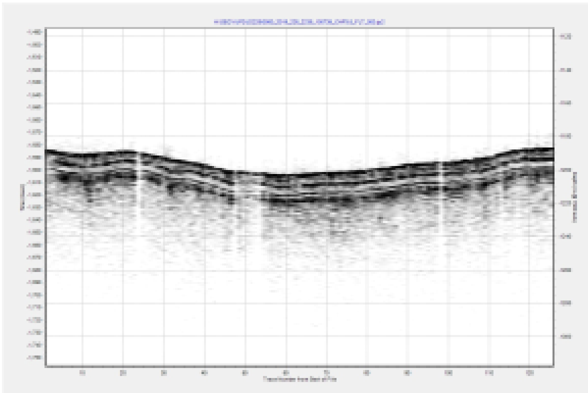

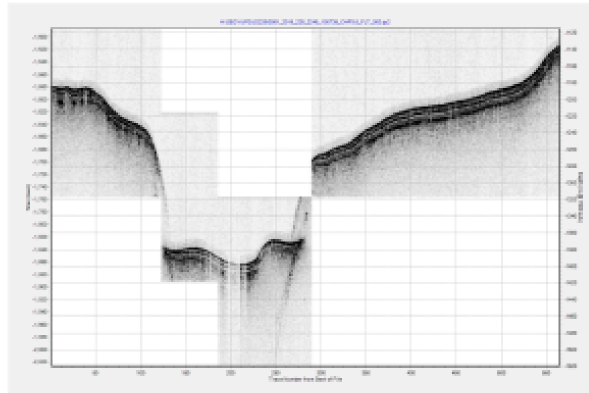

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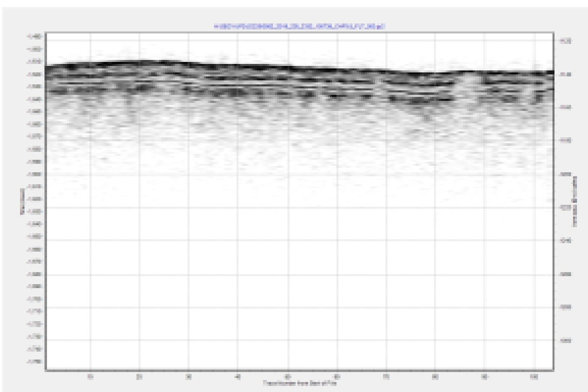

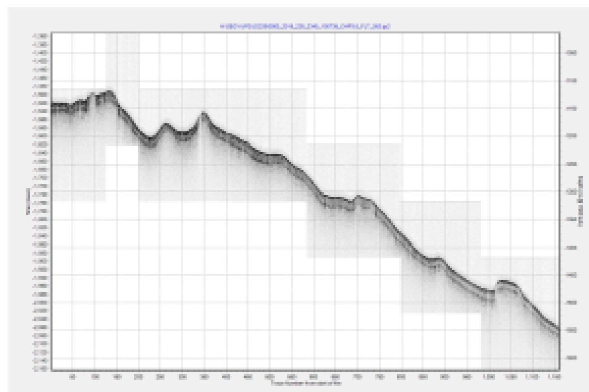

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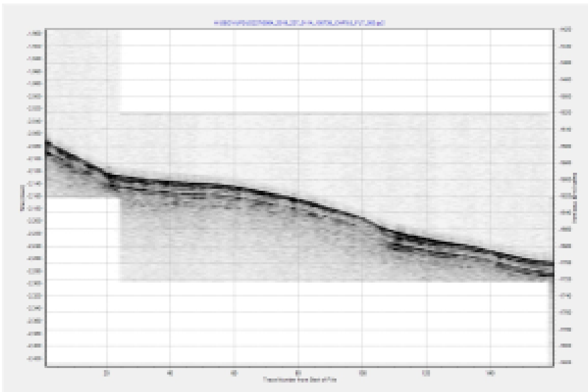
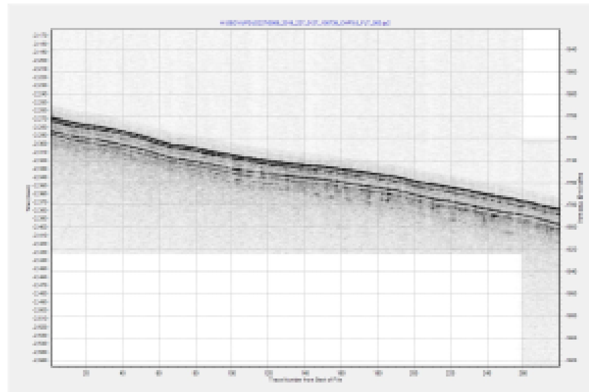
JD227





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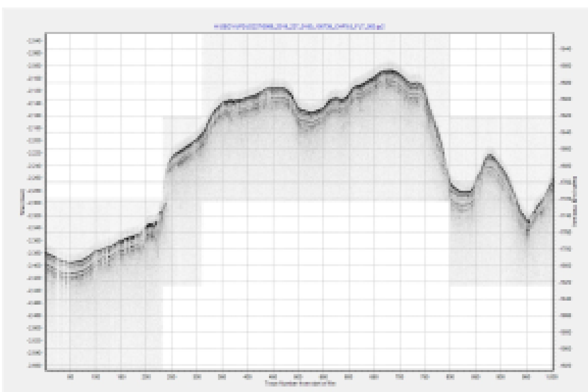

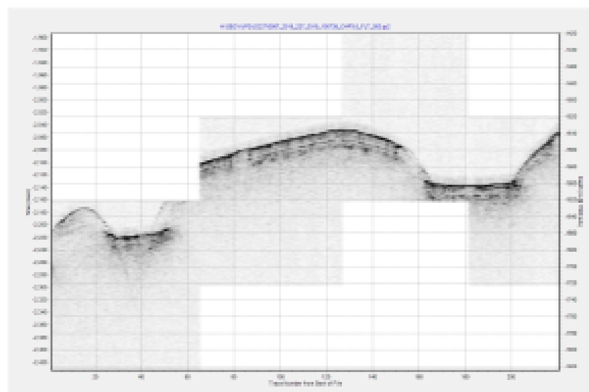

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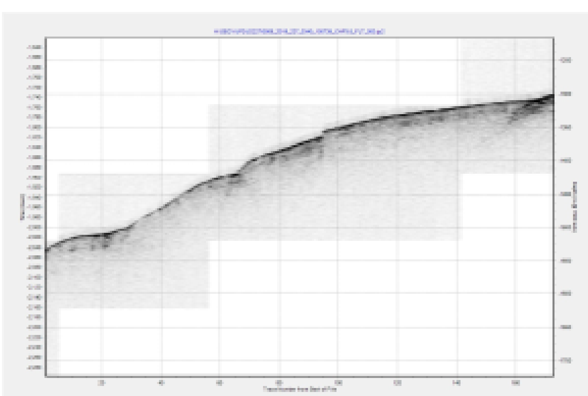

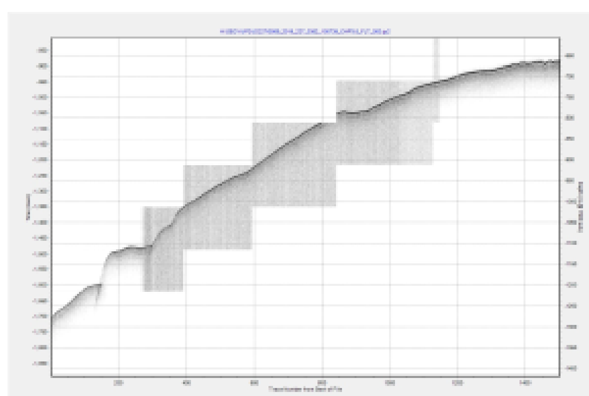

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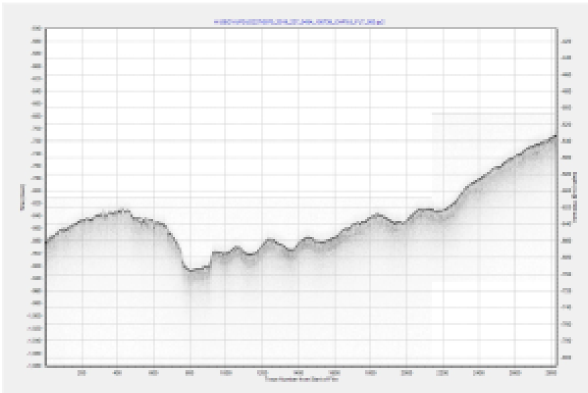

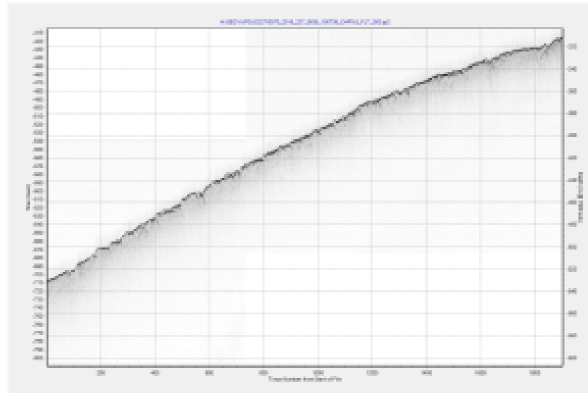

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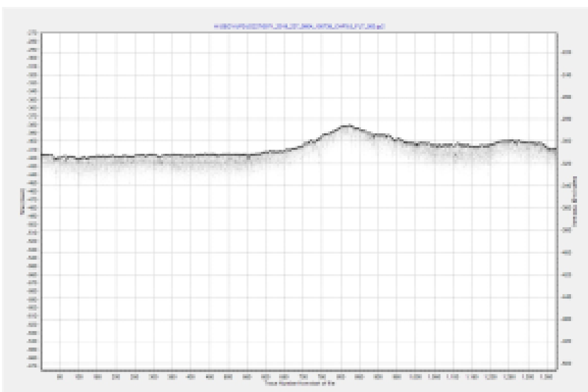

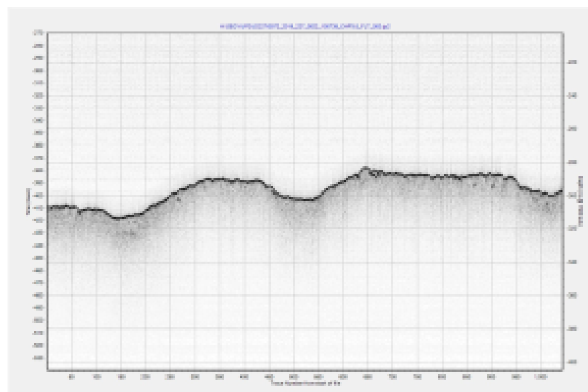

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