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CCGS Hudson Expedition 2015-018 Geological investigation of potential seabed seeps along the Scotian Slope, June 25-July 9, 2015

D.C. Campbell and A.W.A. MacDonald

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

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1 Acknowledgments-

On behalf of the scientific staff of Hudson 2015-018, the Atlantic division of the Geological Survey of Canada at BIO and the Nova Scotia Department of Energy, we would like to thank the Commanding Officer Catherine Lacombe, the deck crew led by Bosun Richard Coolen, the engineering department under the direction of Derrick Coolen, as well as the entire ship's complement for continuous support in execution of the scientific objectives. Several staff contributed content to this expedition report (K. Jarrett, A. Robertson, J. Higgins, T. Fralic, C. Hubert and J. Webb).

- Calvin Campbell and Adam MacDonald, Co-Chief Scientists, Hudson 2015-018

2 Background and Objectives

CCGS Hudson Expedition 2015-018 was a joint mission between the Geological Survey of Canada (GSC) Geoscience for New Energy Supply (G-NES) Program and the Nova Scotia Department of Energy (NSDE). The study area was the continental slope off Nova Scotia.

Seabed hydrocarbon seeps occur where hydrocarbons migrate from depth and escape at the seabed. They are relatively common features in petroleum basins around the world. The detection and sampling of seeps at the seabed is a strong indicator that an active petroleum system is present and provides critical information about the hydrocarbon source, migration pathways, and maturity (Abrams 2013). However, hydrocarbon seeps are notoriously difficult to sample because of their ephemeral nature and environmental complexities. The GSC has a long history of studying the marine geology offshore Canada. In 2015, a joint research project was undertaken by the NSDE and the GSC to investigate and sample seabed hydrocarbon seep features along the continental slope of Nova Scotia. Hudson 2015-018 was the first research expedition of the collaborative project. The science team comprised geologists and technicians from the GSC, geologists and geochemists from NSDE, and geomicrobiologists from the University of Calgary. In total, the scientific team consisted of 23 participants.

In order to determine the most appropriate areas for sampling, a multidisciplinary approach was applied which utilized all available seismic reflection data, interpretations of sea-surface hydrocarbon slick occurrences imaged in satellite data, and near real-time assessment of seabed and water column anomalies using multibeam echosounder and high resolution seismic reflection systems. During the expedition, core samples were processed on board and subsampled for conventional organic geochemical analysis and geomicrobiology. Besides understanding the petroleum system, the core samples collected during this research project serve other important research needs including improved understanding of the microbiology of bacteria living in the sediment and geological hazard assessment.

3 Participants

	Last Name	First Name	affiliation
1	Campbell	Calvin	NRCan
2	Belliveau	Mike	Geoforce
3	Brown	Owen	NRCan
4	Campbell	Lori	NRCan
5	Chakrabortty	Anirban	University of Calgary
6	Cramm	Margaret	University of Calgary
7	Fan	Linda	NRCan
8	Fralic	Tom	Geoforce
9	Fraser	Paul	NRCan
10	Higgins	Jenna	NRCan
11	Hubert	Casey	University of Calgary
12	Jarrett	Kate	NRCan
13	Loch	John	Environment Canada
14	Li	Carmen	University of Calgary
15	MacDonald	Adam	Nova Scotia Department of Energy
16	MacKillop	Kevin	NRCan
17	MacLean	Emily	NRCan
18	Manning	Des	NRCan
19	Murphy	Bob	NRCan
20	Patton	Eric	NRCan
21	Poirier	Simon	NRCan
22	Robertson	Angus	NRCan
23	Webb	Jamie	APTec

4 Summary of Activities

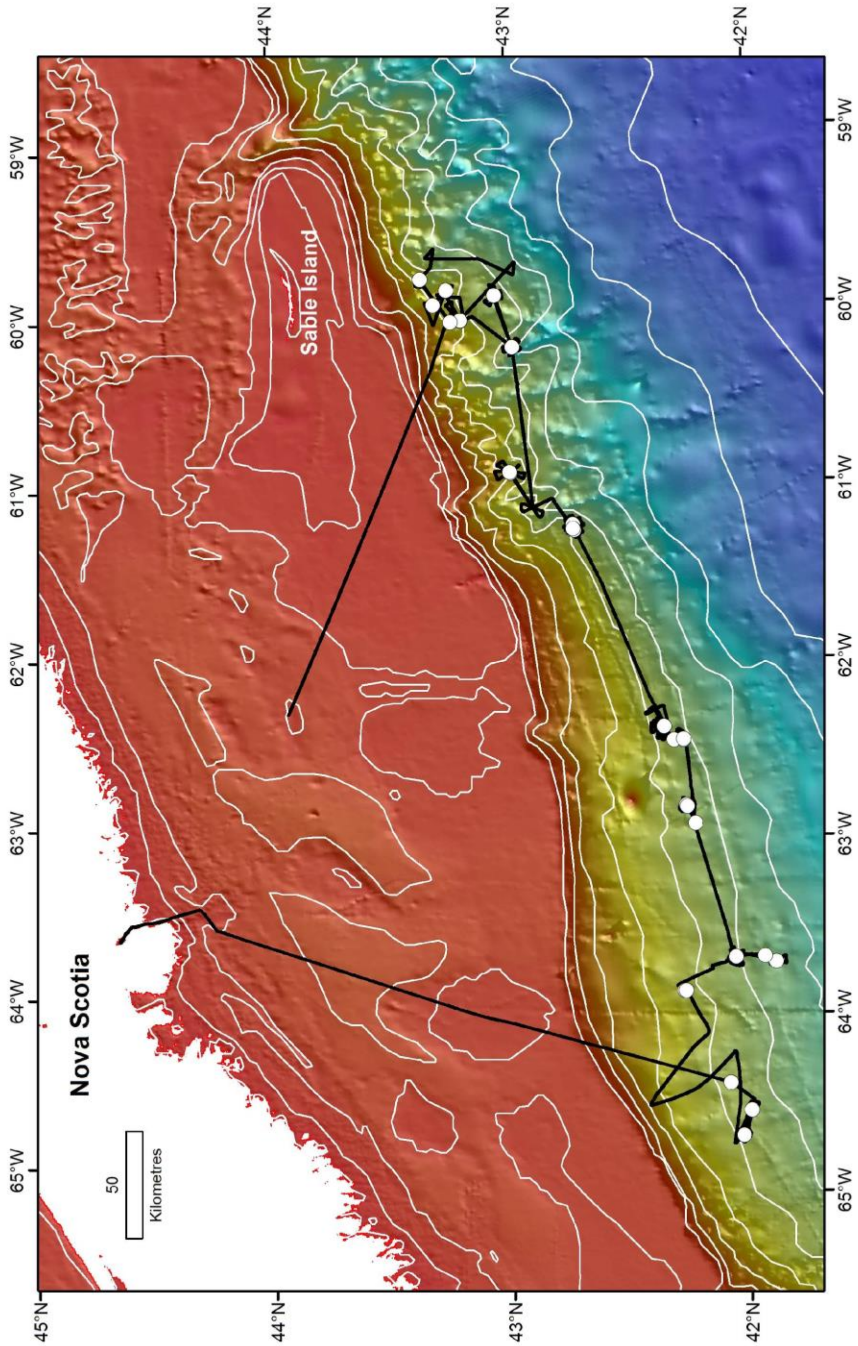

Figure 4.1- Track map and sample locations for Hudson 2015-018.

Table 4.1- Summary of daily activities for Hudson 2015-018.

Date	day/night	loaction	Activity	Station	Survey	notes
25-Jun	day	BIO	Mobilization			Mobilization delays
25	night	BIO	Mobilization			Mobilization delays
26	day	BIO	Steaming			Depart at 1630
26	night	Scotian Shelf	Steaming			Steaming to first core site
27	day	Scotian Slope	Sampling	Core 001		Coring, possible camera
27	night	Scotian Slope	Surveying		Huntec, 3.5 kHz, multibeam	Huntec issues
28	day	Scotian Slope	Sampling	AGI 002, Core 003		Winds build during day
28	night	Scotian Slope	Surveying		3.5 kHz	Only 3.5 kHz due to sea state
29	day	Scotian Slope	Sampling	Core 004, Core 005		gassy cores
29	night	Scotian Slope	Surveying		Huntec, 3.5 kHz, multibeam	Huntec issues
30	day	Scotian Slope	Sampling	Cores 006-008		gassy cores, Pengo issues limiting working depth
30	night	Scotian Slope	Surveying		Huntec, multibeam	
01-Jul	day	Scotian Slope	Sampling	Cores 009-011		
1	night	Scotian Slope	Surveying		Huntec, multibeam	
2	day	Scotian Slope	Sampling	Cores 012-014		submarine cables prevent coring at a location.
2	night	Scotian Slope	Surveying		Huntec, multibeam	
3	day	Scotian Slope	Sampling	Core 015		transit during the afternoon
3	night	Scotian Slope	Surveying		Huntec, multibeam	
4	day	Scotian Slope	Sampling	Cores 016-018		
4	night	Scotian Slope	Surveying		Huntec, multibeam	
5	day	Scotian Slope	Sampling	Cores 19-20		Issues with Piston Corer
5	night	Scotian Slope	Surveying		Huntec, multibeam	

6	day	Scotian Slope	Sampling	Cores 21-23		
6	night	Scotian Slope	Surveying		Huntec, multibeam	
7	day	Scotian Slope	Sampling	Cores 24, 25, 27, AGI 26		Pengo issues
7	night	Scotian Slope	Surveying		Huntec, multibeam	
8	day	Scotian Slope	Sampling	Cores 28-29		Terminate science program at 1230.
8	night	Scotian Slope	Steaming			
9	day	BIO	BIO			Arrive at BIO in the morning

5 Daily Narrative

(all times in Atlantic Daylight Time)

JD 176, Thursday June 25, 2015

Our original sail date was delayed due to re-spooling of the Pengo winch and late delivery of the multibeam system. It was decided to delay departure to the next day.

JD 177, Friday June 26, 2015

We departed BIO at 1430. We conducted a test of the multibeam system in Bedford Basin. Several errors that were reported by the POS-MV were eventually fixed. A patch test was not undertaken in order to not delay departure further. A test deployment of the piston corer was undertaken to bring new deck crew up to speed on procedures. A fire and boat drill was conducted. The coring lesson proceeded until 2230. We departed Bedford Basin for the first site at 2230.

JD178, Saturday June 27, 2015

We transited overnight towards the first core site. A science meeting was held at 0800. The ship arrived at the first core site at 1230. Piston core 001 was on bottom at 1430. The target was above a salt diapir where faults cut amplitude anomalies above the diapir and come near the surface. We transited 2 km northeast of Station 001 and deployed the multibeam pole and Huntec. Heading issues and various acquisition issues with the multibeam system were sorted out over the night. It was a brand new system, and some time was required for the operators to become familiar with the system. Huntec failed at 2330 and was recovered. We switched over to 3.5 kHz system for the rest of the night.

JD 179, Sunday June 28, 2015

We recovered the multibeam pole at 0630. Upon recovery of the pole, an oily sheen was visible off the starboard quarter deck. An AGI slick cast was attempted off the bow (station 02); however, by the time the sampler was deployed the slick was no longer obvious. We transited to the first core site of the day (station 03). The target was a location where a fault associated with a diapir came near the seabed. The Huntec data showed a broad mound at the seabed. Winds came up during the day and coring operations were shut down by lunch time. The engineering department conducted an engine test. We collected 3.5 kHz in a comfortable direction while winds died down over the evening into the night.

JD 180, Monday June 29, 2015

We arrived at the first core site at 0700. The 3.5 kHz data showed widespread acoustic wipeouts in the area. We collected cores 004 and 005 in area of acoustic wipeouts. Core 005 showed gas cracking at the base. We transited 25 km to the south and deployed the multibem pole and the Huntec at 1700. The Huntec failed at 1830 and was recovered. We switched over to 3.5 kHz. Overnight, we ran two small grids of lines over potential coring sites.

JD181, Tuesday June 30, 2015

We ran the survey pattern until 0645. The first core target was near the crest of a buried salt diapir. The 3.5 kHz data showed abundant vertical wipe outs. The multibeam data appeared to show a distinct pockmark about 150 m in diameter. Core 006 was taken in the pockmark. The recovered core was very gassy and had a cottage cheese texture with large voids in the core. Upon recovery of the core, a slick was recognized at the surface in the vicinity of the ship. We conducted two AGI Casts at the location (Station 0007). During recovery of the core, issues were encountered with the spooling of the Pengo wire, as wraps beyond 2500 m were digging into the underlying wraps. The decision was made by the Captain and Chief Engineer to limit the maximum coring depth to 2400 m. We transited upslope to the location of a mound on the seabed. We collected piston core 008 on top of the mound. The core did not appear gassy. We transited 20 km east towards the next survey area and deployed the Huntec and multibeam pole. We surveyed a grid pattern overnight.

JD 182, Wednesday July 1, 2015

We recovered the multibeam pole and Huntec at 0630. An issue occurred with data logging on the multibeam system overnight due to a leap-second being added to the GPS clock. The Huntec data showed a ridge with stratified sediments that is surrounded by mass transport deposits on the intervening valleys. Some possible wipeouts and shallow faults were recognized on the eastern scarp of the ridge. Core 009 was collected in the faults scarp and penetrated mass transport deposits. There was some minor cracking on the bottom section of the core. We transited to site 010 on the stratified ridge crest but the corer had poor core recovery. Core 011 was recovered from what was interpreted as a shallow fault on the ridge crest on the Huntec. Again, there was relatively poor recovery. We transited towards the next site and deployed the Huntec and multibeam pole at 1715. We ran site survey lines overnight.

JD 183, Thursday July 2, 2015

We recovered the Huntec and multibeam pole at 0615. Several good looking core sites were selected, however they all occurred within 1 km of a submarine cable and could not be cored. Instead, we moved west 2 km to a site where several gas indicators were identified in the Huntec data. Core 012 was collected on a terrace with acoustic wipeouts. We transited 3 km upslope to a site where a shallow fault was interpreted to come near the surface and collected core 013. We transited back to the site at the start of the day to try another location on the gassy terrace (Piston Core 014). There were no obvious signs of gas cracks in core. We deployed Huntec and multibeam pole at 1800 and began surveying.

JD184, Friday July 3, 2015

We recovered the multibeam pole and Huntec at 0700. The site survey showed only one good target in the area. Piston core 015 targeted a depression that showed abundant acoustic wipeouts on the Huntec and 3.5 kHz data. The core did not show any evidence of gas expansion. We transited 100 km towards the east, just west of Verrill Canyon, where the seabed is more eroded and a large salt diapir has seabed expression. We conducted a fire drill during the transit. We deployed the Huntec and multibeam pole at 1600. We conducted a survey grid pattern over a salt diapir overnight.

JD185, Saturday July 4, 2015

We recovered the multibeam pole and Huntec at 0600. We transited to core site 016 which was a hummocky and gassy-looking location on the flank of the diapir. Core 017 also targeted a reflective depression on the margin of the diapir. Both cores had poor recovery. Piston Core 018 was collected on the crest of the diapir. There were no signs of obvious gas expansion in any of the cores. Upon splitting, core 018 showed abundant sand layers that were black and smelled of sulfur. We transited 20 km towards the east and deployed the multibeam pole and Huntec at 1700.

JD 186, Sunday July 5, 2015

Winds picked up to 20 kts over night. We recovered the multibeam pole and Huntec at 0600. The first coring site was a location with abundant wipeouts on the Huntec data and where it is interpreted that a deep seated fault comes close to the seafloor. Piston cores 019 and 020 were both essentially from the same location (about 250 m apart). We transited 20 km to the west and to another core location which was a similar setting to cores 019 and 020, although over a different diapir. Upon arriving at the site, an issue was discovered with the piston corer; a piece of liner was stuck in the top of the head which took some time to remove. It was decided to instead transit 70 km to the east and deploy the Huntec and multibeam pole for the night. Deployed gear at 1700.

JD187, Monday July 6, 2015

We recovered gear at 0630. We transited to first core site. Core 021 targeted a fault that had surface expression on the seabed and could be traced down to a buried salt diapir. We transited 25 km to the west to core site 022 which was into acoustically stratified sediment that showed gassy wipeouts in the subsurface. Core 023 was a duplicate of core 022 in order to meet some of the research needs of the geomicrobiologists. We deployed the multibeam pole and Huntec at 1720.

JD188, Tuesday July 7, 2015

We recovered the Huntec and multibeam at 0620. We transited to the first core site. Core 024 was taken at a location where a deep fault comes near the seabed and a depression was identified on the Huntec profile. In addition, the multibeam bathymetry seemed to show water column anomalies over the site. The base of the core showed black mottles and had a sulfur smell. We transited 8 km to the next core site. Core 025 also targeted a location where it is interpreted that a deep fault comes near the surface. The location coincides with an elliptical depression on the seabed. We transited to the next core site which was located on a large seabed mound that coincides with a large buried salt diapir. Upon arrival, issues were encountered with the Pengo that required 2 hours to fix. There was a widespread film on the seabed at the location and an AGI cast was deployed (Station 026). We took core 027 at the location after the winch repairs were complete. We deployed the multibeam pole and Huntec at 1720 and ran lines over night.

JD189, Wednesday July 8, 2015

We recovered the Huntec and multibeam at 0620. We transited to first core site. Core 028 was taken near the location of the Annapolis G-24 well as a calibration site for the geomicrobiology research. We transited 25 km to the east to a distinct wipeout identified on Huntec data. Piston core 029 was the final sample of the program. The core was on deck at 1140 and we began transiting back to Halifax. End of science program.

6 Preliminary Results

6.1 Cruise statistics

6.1.1 Geophysics

1) 750 line-km of 3.5 kHz sub-bottom profiler data was collected using the Knudsen hull-mounted system onboard Hudson.

2) 975 line-km of Huntec DTS Sparker seismic reflection data was collected.

3) 1685 km^2 of multibeam data was collected using the Reson 7160 pole-mounted multibeam.

6.1.2 Samples

29 samples were collected during Hudson 2015-018 consisting of 26 piston cores and 3 AGI slick samples (Tables 6.1 and 6.2).

Table 6.1- Station location and reference seismic reflection information for 2015-018.

Station	Type	Station DayTime	Latitude	Longitude	Water Depth	Expedition Site Selection	Site Selection DayTime	Site Selection Data Type
0001	Piston-AGC Large	178/1731	42.112938	-64.40527	2082	2015018	1781539	3.5KHZ
0002	AGI Slick Sample	179/1155	42.020333	-64.5565	2195	2015018	1782315	HUNTEC
0003	Piston-AGC Large	179/1206	42.052693	-64.700206	2016	2015018	1790125	HUNTEC
0004	Piston-AGC Large	180/1120	42.310676	-63.886528	1763	2015018	1800939	3.5KHZ
0005	Piston-AGC Large	180/1623	42.304856	-63.888131	1837	2015018	1800926	3.5KHZ
0006	Piston-AGC Large	181/1132	41.92713	-63.71642	2648	2015018	1810933	3.5KHZ
0007	AGI Slick Sample	181/1401	41.975491	-63.684076	2600			
0008	Piston-AGC Large	181/1638	42.097695	-63.693831	2360	2015018	1810206	3.5KHZ
0009	Piston-AGC Large	182/1106	42.30861	-62.836325	2284	2015018	1820011	HUNTEC
0010	Piston-AGC Large	182/1448	42.304891	-62.843611	2257	2015018	1820005	HUNTEC
0011	Piston-AGC Large	182/1811	42.270058	-62.93806	2327	2015018	1821811	3.5KHZ
0012	Piston-AGC Large	183/1121	42.321158	-62.467133	2324	2015018	1830216	HUNTEC
0013	Piston-AGC Large	183/1500	42.360211	-62.465481	2208	2015018	1830145	HUNTEC
0014	Piston-AGC Large	183/1857	42.321323	-62.462953	2328	2015018	1822317	HUNTEC
0015	Piston-AGC Large	184/1149	42.402196	-62.389195	2178	2015018	1841931	HUNTEC
0016	Piston-AGC Large	185/1047	42.774881	-61.234878	2233	2015018	1850141	HUNTEC
0017	Piston-AGC Large	185/1414	42.771301	-61.266595	2187	2015018	1842245	HUNTEC
0018	Piston-AGC Large	185/1719	42.775798	-61.259595	2084	2015018	1842336	HUNTEC
0019	Piston-AGC Large	186/1046	43.035063	-60.932885	1522	2015018	1860232	HUNTEC
0020	Piston-AGC Large	186/1338	43.03667	-60.929335	1520	2015018	1860234	HUNTEC
0021	Piston-AGC Large	187/1055	43.080551	-59.9134	2320	2015018	1870755	HUNTEC
0022	Piston-AGC Large	187/1442	43.013106	-60.213735	2342	2015018	1870100	HUNTEC
0023	Piston-AGC Large	187/1811	43.013181	-60.213841	2342	2015018	1870100	HUNTEC
0024	Piston-AGC Large	188/1035	43.340303	-59.958476	1540	2015018	1880907	HUNTEC
0025	Piston-AGC Large	188/1323	43.282571	-59.876886	1854	2015018	1880424	HUNTEC
0026	AGI Slick Sample	188/1550	43.228066	-60.054783	1734			
0027	Piston-AGC Large	188/1841	43.227075	-60.051148	1671	2015018	1880111	HUNTEC
0028	Piston-AGC Large	189/1049	43.39115	-59.809085	1679	2015018	1890838	HUNTEC
0029	Piston-AGC Large	189/1351	43.270203	-60.05894	1620	2015018	1872239	HUNTEC

Table 6.2- Detailed core recovery and performance information for 2015-018.

Station Number	Core Type	Core Length	Number of Core Sections	Core Catcher Present	Apparent Penetration	Corer Length	Comments
1	Piston	834	7	YES	1219	1219	In water 1647, back at surface 1830, pengo cable jumping on the winch, CD sediment slightly dimpled, A'A" 5cm whole round for geochem, AA' 20cm whole round for U of Calgary, catcher 6cm, cutter 17cm, tip 6cm, core split on board.
1	Trigger	207	N/A	NO	N/A	N/A	No Comments
3	Piston	555.5	5	YES	1158	1219	In water 1113, at surface 1332, A'A" 5cm whole round for geochem, AA' 20cm whole round and entire TWC for U of Calgary, catcher/cutter 19.5cm, core split on board.
3	Trigger	171	N/A	NO	N/A	N/A	No Comments
4	Piston	770	6	NO	1249	1219	In water 1043, at surface 1205, A'A" 5cm whole round for geochem, AA' 20cm whole round for U of Calgary, CC'3.5cm, EE' 2cm, tip 6cm, core split on board.
4	Trigger	31	N/A	NO	N/A	N/A	No Comments
5	Piston	785	6	YES	975	1219	In water 1547, CD sediment slightly dimpled, A'A" 5cm and AA' 15cm whole rounds for U of Calgary, top of section AB expanded in reefer so BB' 4cm, cutter 21cm, core split on board.
5	Trigger	182	N/A	NO	N/A	N/A	No Comments
6	Piston	597	6	YES	1158	1219	Gassy core, CD sediment slightly dimpled and PC catcher completely inverted, A"A"' and A'A" 5cm whole rounds for geochem, AA' 15cm whole round for U of Calgary, catcher 6cm, cutter 17cm, tip 6cm,

Station Number	Core Type	Core Length	Number of Core Sections	Core Catcher Present	Apparent Penetration	Corer Length	Comments
							core split on board.
6	Trigger	204	N/A	NO	N/A	N/A	No Comments
8	Piston	1029	7	YES	1249	1219	In water 1551, catcher totally inverted, GH liner imploded approx 1/2 way down, broken liner pieces at top and sediment disturbed, A'A" 5cm and AA' 15cm whole rounds for U of Calgary, catcher 4cm, core split on board.
8	Trigger	203	N/A	NO	N/A	N/A	No Comments
9	Piston	473	4	YES	701	1219	In water 1021, minor gas cracking at base, A"A"'and A'A" 5cm whole rounds for geochem, AA' 15cm whole round for U of Calgary, TWC catcher 4cm, PC catcher/cutter 20.5cm, core split on board.
9	Trigger	141	N/A	YES	N/A	N/A	No Comments
10	Piston	537	5	YES	670	1219	In water 1401, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, PC cutter 20cm, tip 16cm, core split on board.
10	Trigger	203	N/A	NO	N/A	N/A	No Comments
11	Piston	405	4	YES	548	1219	In water 1725, TWC likely fell over, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, PC catcher/cutter 16cm, tip 6cm, core split on board.
11	Trigger	51	N/A	NO	N/A	N/A	No Comments

Station Number	Core Type	Core Length	Number of Core Sections	Core Catcher Present	Apparent Penetration	Corer Length	Comments
12	Piston	927.5	7	YES	1280	1219	In water 1032, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, EE' 4cm, cutter 19cm, core split on board.
12	Trigger	44.5	N/A	NO	N/A	N/A	No Comments
13	Piston	902	7	YES	0	1524	In water 1415, EF 14cm at base of liner cracked, A'A" 5cm whole round for geochem, AA' 15cm whole round and entire TWC taken by U of Calgary, catcher/cutter 20cm core split on board.
13	Trigger	156	N/A	NO	N/A	N/A	No Comments
14	Piston	803.5	7	YES	1280	1219	In water 1809, A'A" 5cm and base of cutter whole rounds for geochem, AA' 15cm whole round for U of Calgary, core split on board.
14	Trigger	216	N/A	NO	N/A	N/A	No Comments
15	Piston	784.5	7	YES	1249	1219	In water 1104, at surface 1256, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, catcher 3cm, cutter 20.5cm, core split on board.
15	Trigger	180	N/A	NO	N/A	N/A	No Comments
16	Piston	683	6	YES	975	1219	In water 1002, at surface 1147, TWC fell over so no recovery but dark grey silty clay on the outside of barrel, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, catcher/cutter 21cm, tip 8cm, core split on board.
16	Trigger	0	N/A	NO	N/A	N/A	No Comments
17	Piston	25	1	NO	487	1219	In water 1337, TWC likely fell over, PC cutter badly damaged likely hit a rock, core

Station Number	Core Type	Core Length	Number of Core Sections	Core Catcher Present	Apparent Penetration	Corer Length	Comments
							split on board.
17	Trigger	22.5	N/A	NO	N/A	N/A	No Comments
18	Piston	812	7	YES	1463	1524	In water 1637, possible labeling issue with CD and DE in the half height but OK when split, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, EE' 2cm, cutter 26cm, tip 10cm, core split on board and entire working half of TWC was subsampled.
18	Trigger	22.5	N/A	NO	N/A	N/A	No Comments
19	Piston	665.5	6	YES	1219	1219	In water 1014, at surface 1135, liner imploded approximately 30cm above sediment surface, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, EE' 3cm, catcher cutter and tip 27.5cm, core split on board and 0-12cm of TWC working completely subsampled.
19	Trigger	12	N/A	YES	N/A	N/A	No Comments
20	Piston	687	8	YES	1219	1219	In water 1307, liner imploded at top of core and driven into liner below, base of core 44cm sediment not in liner so put in split liner, top sections IJ (approx 80cm) and HI (approx 85cm) completely destroyed and unable to recover any sediment. A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, cutter and tip 24cm, core split on board and 0-12cm of

Station Number	Core Type	Core Length	Number of Core Sections	Core Catcher Present	Apparent Penetration	Corer Length	Comments
							TWC working completely subsampled.
20	Trigger	26	N/A	NO	N/A	N/A	No Comments
21	Piston	724	6	YES	914	1219	Catcher inverted, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, catcher cutter and tip 23cm, core split on board.
21	Trigger	127	N/A	NO	N/A	N/A	No Comments
22	Piston	690	6	YES	1280	1219	In water 1353, at surface 1445, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, catcher cutter and tip 26.5cm, core split on board and entire TWC subsampled at sea.
22	Trigger	197	N/A	NO	N/A	N/A	No Comments
23	Piston	615	5	YES	1280	1219	In water 1730, at surface 1914, CD and DE liner appears slightly deformed, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, catcher and cutter 22cm, core split on board.
23	Trigger	42	N/A	NO	N/A	N/A	No Comments

Station Number	Core Type	Core Length	Number of Core Sections	Core Catcher Present	Apparent Penetration	Corer Length	Comments
24	Piston	607.5	5	YES	944	1219	In water 1005, sediment in the cutter was very black and A"A"' and A'A" 5cm whole rounds for geochem, AA' 15cm whole round for U of Calgary, cutter 19.5cm, core split on board.
24	Trigger	70	N/A	NO	N/A	N/A	No Comments
25	Piston	645	6	YES	944	1219	In water 1246, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, catcher and cutter 19cm, tip 6cm, core split on board.
25	Trigger	42.5	N/A	NO	N/A	N/A	No Comments
27	Piston	502.5	5	YES	640	1219	In water 1802, top of second barrel liner imploded and pieces of broken liner at sediment surface, TWC cutter silty and stiff and PC cutter very stiff. A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, catcher 3cm, cutter 17cm, tip 11.5cm, core split on board.
27	Trigger	33	N/A	YES	N/A	N/A	No Comments
28	Piston	786	6	YES	1249	1219	In water 1013, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, TWC cutter 17cm, PC catcher cutter and tip 28cm, core split on board.
28	Trigger	33	N/A	YES	N/A	N/A	No Comments
29	Piston	546	5	YES	1249	1219	In water 1319, A'A" 5cm whole round for geochem, AA' 15cm whole round for U of Calgary, TWC cutter 18cm, PC catcher cutter and tip 21cm, core split on board.
29	Trigger	39	N/A	YES	N/A	N/A	No Comments

7 Equipment and Procedures

7.1 Reson 7160 Pole-mounted Multibeam System

The multibeam system that was rented for this expedition was the Reson Seabat 7160. This is the same system that was rented for Hudson 2013-029 and more details are provided in Campbell (2014). The system is a medium depth sonar (frequency: 44 kHz) with depth capabilities to 3000 m. CHS Atlantic assisted in the mobilization of the system. A survey of the offsets (Between sonar head, multibeam, GPS antennas) was completed prior to sailing.

The system was installed on a pole at the rear quarter deck, starboard side, of CCGS Hudson. Motion was measured by an Applanix POS M/V Version 5 unit mounted on the pole, near the sonar head. Two heading antennas (Trimble BD960) were mounted on an upper deck with a fairly good view of the sky/satellites. Accuracies were commonly within 0.5 m while in DGPS mode, however going up as high as 2.5 m when not in DGPS mode. Position was supplied to the POS M/V system from the dedicated science GPS. Unfortunately, it was not possible to sync the system with the Huntec DTS which led to significant interference introduced to the data from the Huntec outgoing pulse.

Sound velocity through the water column was obtained by using Lockheed Martin - Sippican expendable sound velocity casts (XSV-02) approximately every 6 hours or if the surface sound speed had large fluctuations.

Preliminary data processing was done on CCGS Hudson to verify incoming data quality and to provide updated coverage daily for science planning. The 1 day data collection to 1 day data processing worked very well. Caris HIPS/SIPS 7.1 was used as the processing software with Caris Base Editor 4.0 to convert data in a usable format for ArcGIS.

Overall, the system performed very well.

7.2 Knudsen 3260 Echo-Sounder

During much of the program a ram mounted 12 kHz transducer, transceiver and recorder were used to track bottom and gather some sub-bottom data when sampling. During transit, or when the Huntec DTS was unavailable during survey, the 3.5 kHz hull mounted transducer was employed. No problems were encountered with this system for the duration of the cruise.

7.3 Huntec Deep Towed System

This section was modified from a report prepared by Tom Fralic at Geoforce Group Ltd.

Geoforce Group Limited provided technicians Tom Fralic and Mike Belliveau
to supervise the installation, operation and maintenance of the Huntec systems during the field program.

7.3.1 Equipment

Deep Tow System

Geoforce Group Limited of Dartmouth, Nova Scotia was contracted to supervise the operation, maintenance and ongoing engineering development of the NRCan's Deep Tow Seismic (DTS) systems. The DTS system, originally manufactured by Huntec (70) Limited, is a high resolution, subbottom profiler with the acoustic source, energy supply, motion sensor, and two receiving hydrophones housed in an underwater tow fish.

The AGC #3 DTS system was used on this mission. The maximum power output of this system is 1000 joules (60 µF storage capacitance) with an ED10FC Boomer and a twenty tip mini sparker source. For this mission, the internal single element LC10 hydrophone was configured as Seismic #1. The externally towed Geoforce GF24/24P2i streamer hydrophone was connected as Seismic #2 (overall streamer length 24 feet, two interspliced channels with a combined fourteen foot active section, total of twentyfour AQ1 elements with an effective spacing of 12 inches).

The ED10FC boomer source is depth compensated and outputs a highly repeatable broadband pulse, capable of resolving 10 cm. Peak output intensity is 219.5 dB/1µPa @ 1m, with a pulse duration of 110 microseconds. The sparker source has twenty, #18 awg, solid core tips. The peak amplitude and pulse width of the sparker source are depth dependent. Acoustic output is centered at approximately 1500 Hz, with a bandwidth of 500-2500 Hz. The sparker source was used exclusively on this mission. The deck equipment consists of a Benthos Oceanographic winch, which includes a multiway slip ring and a 600 m, fourteen conductor, armored tow cable. The winch is powered by a 440 VAC, 50 HP hydraulic pump unit.

The tow cable is handled by a 36 inch diameter roller cluster rigged on the center position of the aft A frame. The lab instrumentation consists of the Geoforce MK II Systems Console and DC high voltage power supply (PCU). The Systems Console houses the Bottom Motion Compensator circuits, the +60 DC volt fish supply, and modules for signal processing and recorder outputs. The Huntec Mk III PCU provides DC power to the Energy Storage Unit (ESU) in switchable ranges from 2 to 6 kilovolts.

Geoforce also brought their own manufactured DTS, this is a new system with 1000 Joule firing capability. It is a smaller system than the AGC#3 unit. This unit shared the PCU, winch, and recording units with AGC#3. A Mk III Systems Console was used, this unit is equipped to run at either 110VAC or 240VAC; it also has a different programming configuration to digitize the Pitch and Roll signals which are different voltages from the new clinometers Attitude Sensor Unit.

Recording Systems

A GeoDigs 24 Bit Acquisition System (DIGS #2) was used as the digital recording device. This included a National Instruments USB 9234 Analog to Digital Converter, and GeoDigs v1.3 software operating on a laptop running Windows 7. Master Trigger was from Geoforce System Consoles. Navigation Data came via the bridge through the laptop's Ethernet port and was decoded with Dimension.

Paper records were generated by an EPC 9800 Graphic Recorder using the parallel interface functionality of the Portable DIGS #2 system. Automatic and user initiated annotation of the paper records were provided using the annotator function of the DIGS software.

Recording Parameters

<u>DTS System Console</u>

BMC: Enabled
Trigger Source: Internal Console Trigger
Trigger Rate: 1s, 1.25s, 1.5s, 1.75s, 2s, 2.5s (changes in log)
TVG Rate: 0 (max)
Source Level: 4kV

<u>Portable DIGS #2</u>

Software: GSCA USB 9234 Mk. 1.3.1
Format: SEG Y
Storage Medium: Internal Hard Disk Drive
Sample Rate: 25.6 kHz
Record Length: 500 ms
Trigger I/P: Geoforce Systems Console Master Trigger
Analog I/P 1: DTS Internal Raw
Analog I/P 2: DTS External Raw
Analog I/P 3: Unused

<u>EPC 9800</u>

Display: DTS External Stremer
Print Density: 100 LPI
Print Gain: 36 dB (Typical)
Print Delay: 1500 ms (Typical)
Print Threshold: 0 (Typical)
Fix Marks: Timestamp @ 5 min. intervals
Scale Lines: 100 ms
Low Cut Freq.: 500 Hz
Hi Cut Freq.: 12800 Hz

7.3.2 Equipment Performance

DTS

The survey started with using the Geoforce DTS™ as the main system. System was lab tested and tested off the deck of the Hudson. The system was towed between 62m72m. Despite this, after roughly 5 hours of collecting data, signals were lost and leak alarm was sounding. Once pulled up on board the system was taken apart and it was discovered that there was flooding in the ESU. At this time it was determined that the flood came from the new high voltage cable equipped with the DTS. Within the ESU, all the SCR's were shorted and there were clear arcing to the stainless steel cylinder. All the SCR's were replaced and continuity checked out, system was tested on deck and boomer fired at 2kV. System was deployed again the next day (JD 180), after being towed at ~70m, leak alarm went off and system was brought on board. It was determined that sea water was hosing in through the High Voltage cable via the Sparker Coil. This is normally prevented with water blocks, which this system was lacking. It was noticed that the High Voltage Connector was filled with water as well. At this point, it was decided to switch the system in use to the AGC#3 fish. There were no issues with this system throughout the remainder of the survey.

Portable DIGS #2

This recorder operated the entire program without issue with one exception. At one night it was discovered that the "break files at 1 hour length" was not selected. This made closing the program worrisome as it was "hanging up," and instead of several medium sized SEGY files, there was one very large file, making processing slower.
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EPC 9800

This recorder operated the entire program without issue.

Consumables

No sparker tips needed to be changed during this survey. From the Spares kit, 8 SCRs were used to repair Geoforce's DTS, which were replaced by Geoforce following the cruise.

7.4 Piston Coring

The piston coring system used was the AGC Long Corer which uses coupled core barrel sections in 10 ft (305 cm) lengths. In deep water the device is typically rigged using a maximum of four or five barrels. During this cruise the system was typically rigged with four barrels (1220 cm), except for stations 13 and 18 (5 barrels, 1525 cm). The core head itself is 3 m long, 0.6 m in diameter and weighs approximately 1350Kg. Each barrel has an ID of 4.25" (10.8cm), a 3/8" (9.5mm) wall thickness with twin exterior Victaulic type grooves cut at each end. Pipe sections are joined using exterior couplings which are secured by set screws into grooves. The barrels are lined with Cellulose acetate butyrate (CAB) plastic pipe which is also in 10 ft (305cm) lengths to return sediment core samples with an OD of 99.2 mm. A split piston with O-rings and a variable orifice size (split piston orifice used for the first two cores was 7/64" then we switched to 3/32") and a standard core catcher was used at all coring sites. The trip arm for the core system also supported a 4.25" (10.8cm) diameter gravity corer with a single 7ft (2.14m) 10" barrel and 300 lb (135 kg) head comprised of circular lead weights.

The ship’s large Pengo winch was used for coring with ¾” wire cable. The Pengo wire was respooled prior to sailing under 3rd party contract supervision. The North Pacific foredeck crane was used to deploy and recover the heavy coring equipment and a ship's trawl block was used off the side arm of this crane to hoist the pilot core. A small GSCA tugger winch was used to rig and recover the pilot core plumbed to a DFO power pack. The corer was handled on deck using a system that included a rotating core-head cradle, outboard support brackets, a monorail transport system with 2 one ton chain hoists, a lifting winch and a processing half-height container. Each recovered core was broken down at the barrel joints and moved to the processing half-height container via the monorail, where each 10ft (305cm) section of liner was extruded from the barrel and cut in half and labelled.

The corer worked reasonably well. Liner implosions were minimal. The main issue during this expedition regarding the coring was how the Pengo wire was spooled prior to sailing. It is the chief scientist’s understanding that insufficient tension was applied for the inner wraps and as a result, the combined weight of the wire and the piston corer caused the wire to cut into underlying wraps. This became particularly severe when exceeding 2600 m of cable payout. As a result, the expedition was limited to sampling in water depths less than 2400 m. This was unfortunate because several targets were in 2700-3400 m water depth.

7.5 Onboard piston core processing and subsampling

In total, 200 meters of sediment core was obtained from piston coring. Core sections were split longitudinally from surface and down the core as soon as possible after being collected. The plastic liner was cut longitudinally using the GSC-A Duits splitter and the sediment itself was split longitudinally by pulling a piece of fine wire through the sediment along the cuts in the plastic core liner. The two core halves were designated archive and working. Each half was labelled with an up arrow, cruise number, sample number and section information. Metre tape was placed along the length of the split core section to indicate down-core depth.

The two halves were separated to undergo different analyses. The archive half was photographed, measured for colour reflectance, and described visually. The working half was viewed by Jamie Webb and University of Calgary researchers for selection of subsample locations before being promptly measured for physical properties (velocity, shear strength, bulk density and water content) that change as the core dries. The core halves were covered with plastic wrap, sealed in labeled plastic core sleeving, placed in labelled plastic D-tubes and stored at 4°C in a refrigerated container until their return to BIO.

Core Photography

The archive half of the core was photographed using a Nikon D300 12.3 megapixel digital camera. Overlapping digital photographs were taken at two scales. The first was a close up image covering a 30 cm interval, and the second was a long shot image covering a 90 cm interval. The images were saved in raw, tiff and jpeg formats.

Reflectance Spectrophotometry

High accuracy measurements of spectral reflectance on the split core surface were made over wavelengths of 400 to 700 nm using the Konica Minolta Spectrophotometer CM-2600d. Tristimulus values X, Y and Z were derived from the colour reflectance spectra according to the Commission Internationale d'Eclairage (CIE) method. The L*a*b* system (CIELAB) represents coordinates in 3 dimensional space where the L* is the vertical axis representing lightness and a* b* are horizontal radii representing chromaticity. The L* value ranges from zero (black) to 100 (white). The a* value represents green (-) to red (+) and the b* value represents blue (-) to yellow (+).

A zero calibration was performed to compensate for the effects of any change in the optical system and changes in ambient and internal temperature. White calibration was done using a white ceramic calibration cap and sets the maximum reflectance to 100%. Zero calibrations were performed daily and white calibrations were performed at least once daily. Prior to spectral reflectance measurements the core was carefully covered with Glad® Cling Wrap taking care to minimize the presence of air bubbles between the sediment and the plastic wrap. Measurements on the CM-2600d were taken every 5cm and interfaced with a computer using the SpectraMagicTM NX software.

Sample Description

The written laboratory descriptions for the sediment cores includes: 1) condition of sample (e.g. cracks, disturbance, oxidation), 2) consistency of sample (e.g. soft, hard, firm, 3) reaction to hydrochloric acid which indicates the presence of calcium carbonate, 4) colour based on the Munsell soil colour charts and 5) visual core description consisting of colour, texture, grain size, bedding, contacts, bedforms, structures, presence of organic material, bioturbation and any other visible feature.

Discrete Core Measurements

Discrete velocity

The discrete velocimeter has four transducer probes that were carefully inserted into the split core section and measure pressure (or compressional) wave velocity in the longitudinal and transverse directions to the axis of the core. Longitudinal and transverse velocity measurements were taken at a standard 10cm interval; because sediment is being probed, measurements are only taken in sediments that do not drain. Daily calibrations were done to determine the p-wave travel time delay inherent to the system (i.e. electronics); the delay is calculated for each pair of transducers by measuring the distance between them, determining what the travel time should be in distilled water of known temperature, and then comparing it to an actual measurement of the travel time in distilled water at the known temperature. Each measured p-wave travel time was corrected for the travel time delay and then the p-wave velocity is calculated.

Discrete Shear Strength

Shear strength measurements were made using a motorized miniature vane shear apparatus. A four bladed vane was inserted into the split surface of a sediment core to a constant depth and rotated at a constant rate of 90°/min until sediment failure. Measurements were taken only in undrained and undisturbed soft sediments.

The difference in rotational strain between the top and bottom of a linear spring (deflection angle) was measured and the torque required to shear the cylindrical surface around the vane was calculated. Each vane has a vane blade constant dictated by the geometry of the blade, and each spring has a spring constant that relates the deflection angle to the torque. Peak and remoulded shear strength values were calculated according to ASTM Method D4648. Routine calibration of the system is not necessary. Peak shear strength measurements were taken at a standard 10cm interval and two to three measurements of remoulded shear strength were taken per section.

Constant volume sampling

Constant volume samples were taken using a stainless steel cylindrical sampler of known volume. The sampler, which was lightly greased with vegetable oil spray to minimize friction, was gently inserted into the sediment at a constant rate to avoid compression of the sediment. The sampler with the sediment inside was then carefully removed from the core and the sample was trimmed using a wire saw. The sediment sample was extruded from the cylinder, stored in a glass bottle of known weight, and then sealed to prevent desiccation. The samples were stored in a refrigerated container at 4ºC until return to BIO where they will be weighed, dried at 105ºC for 24 hrs and weighed again. Bulk density and water content values can then be calculated according to ASTM Method D2216-98.

7.6 Geochemical subsampling

All cores collected during 2015-018 were subsampled for geochemical analysis. Upon core retrieval, a headspace gas sample was immediately taken 5 cm from the base of the core. This whole round sample was divided in two, with each half placed in a separate IsoJar, and then flushed with nitrogen. If gas cracking and bubbling or a positive gas detector measurement were present, then additional gas samples were taken.

After the core was split, the working half was viewed under UV light to determine possible presence of hydrocarbon fluorescence. Three sediment samples were then taken per core from a minimum of 1 m from the top of the core, to sample only anoxic sediment. These samples targeted fluorescing sediment, sandier intervals or darkened organic rich bands in the core. The samples were again divided in two and wrapped in aluminum foil. All samples were placed in a -20°C freezer to limit bacterial growth, and remained frozen until they undergo analysis at a lab.

7.7 Geomicrobiology

For the 2015 Hudson expedition, the objective of the Geomicrobiology Group team from the University of Calgary was to contribute exploration de-risking data and results based on different microbiological principles. Bioassay approaches were tested on piston core samples. Samples were processed onboard with a limited number of experiments set up and conducted on the ship (time permitting) and more experiments and analyses undertaken post-expedition in the geomicrobiology research labs in Calgary.

Microbiology results will be integrated with other geoscience data in a broader work program at NSDE that has been designed with oil industry input, including seismic results and geochemical analyses that will be conducted on the same samples. By integrating genomics with extensive geoscience mapping approaches (seismic data, geophysical methods, geochemical tools, satellite oil slick data, etc) the new bioassays will be validated within a comprehensive effort comprising the NSDE's petroleum source rock program. This will support the overall aim of the expedition and NSDE source rock program of reducing front end exploration risk perceived by oil and gas companies.

8 References

Abrams, M.A. 2013. Best practices for the collection, analysis, and interpretation of seabed geochemical samples to evaluate subsurface hydrocarbon generation and entrapment. Offshore Technology Conference Paper 24219. 21 pages.

Campbell, D.C. 2014. CCGS Hudson Expedition 2013-029 geological hazard assessment of Baffin Bay and biodiversity assessment of Hatton Basin, August 14 - September 16, 2013. Geological Survey of Canada, Open File 7594, 2014; 124 pages, doi:10.4095/293694

9 Appendices

9.1 Detailed Sample and Survey location maps

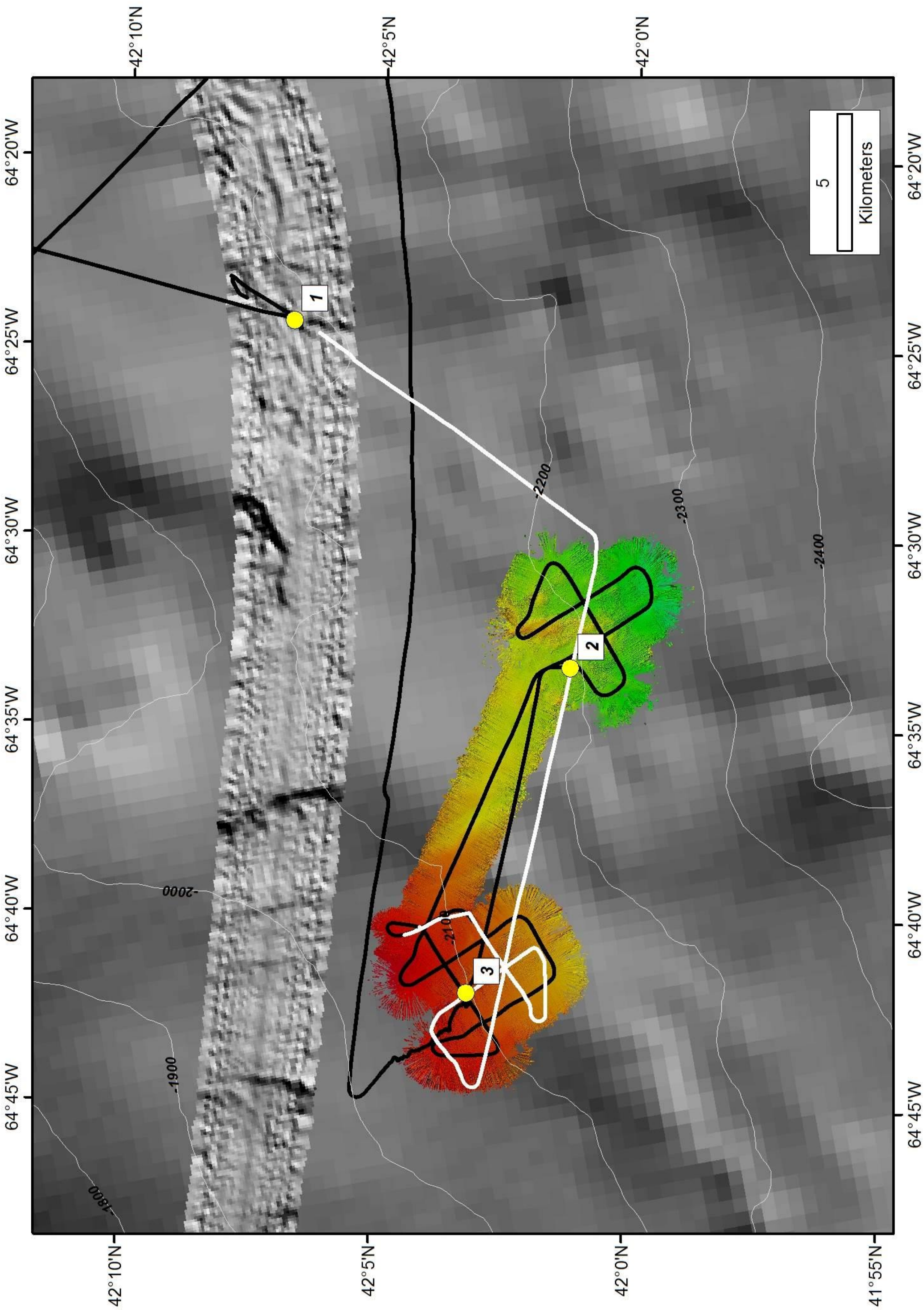

Figure 9.1.1- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

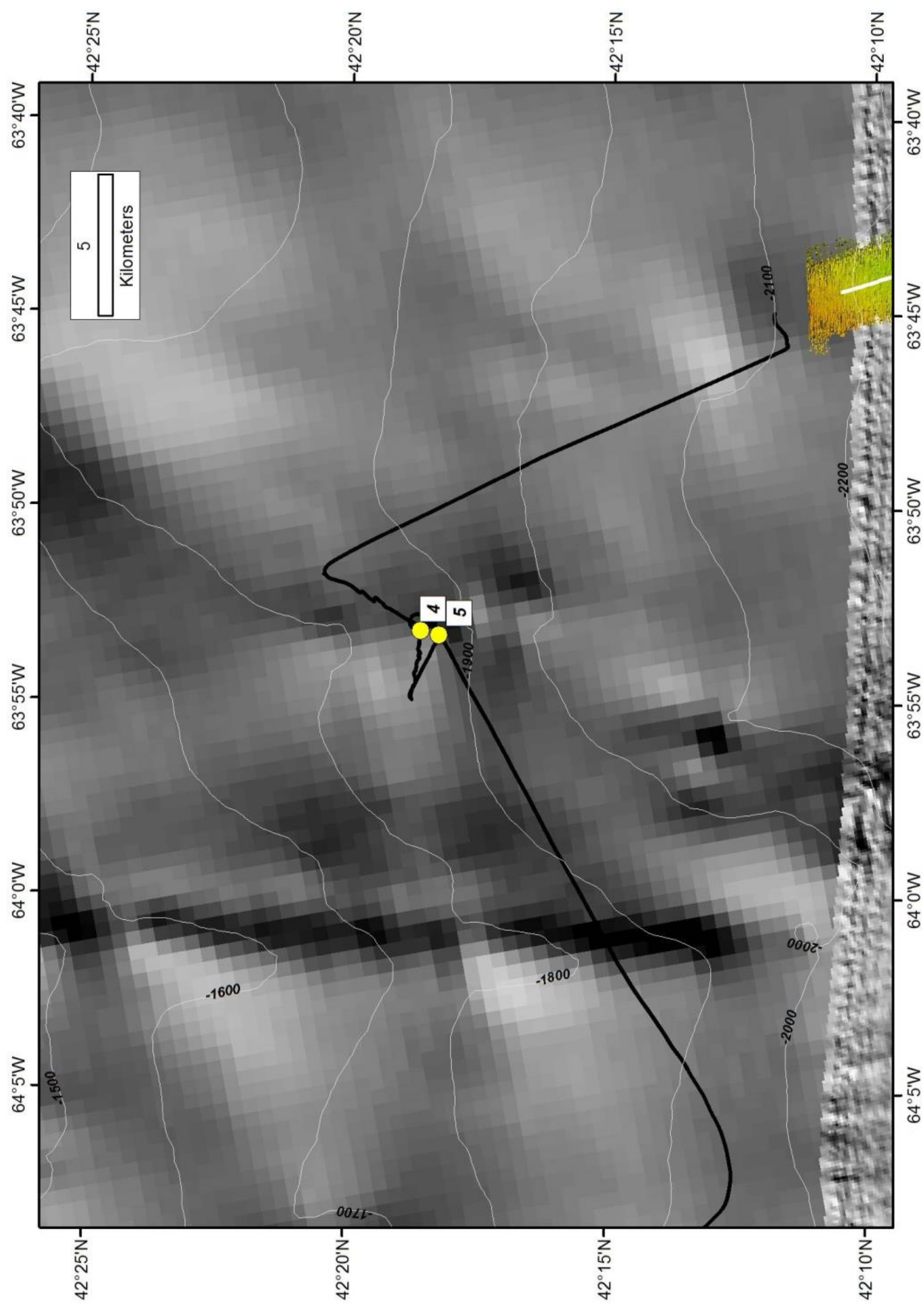

Figure 9.1.2- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

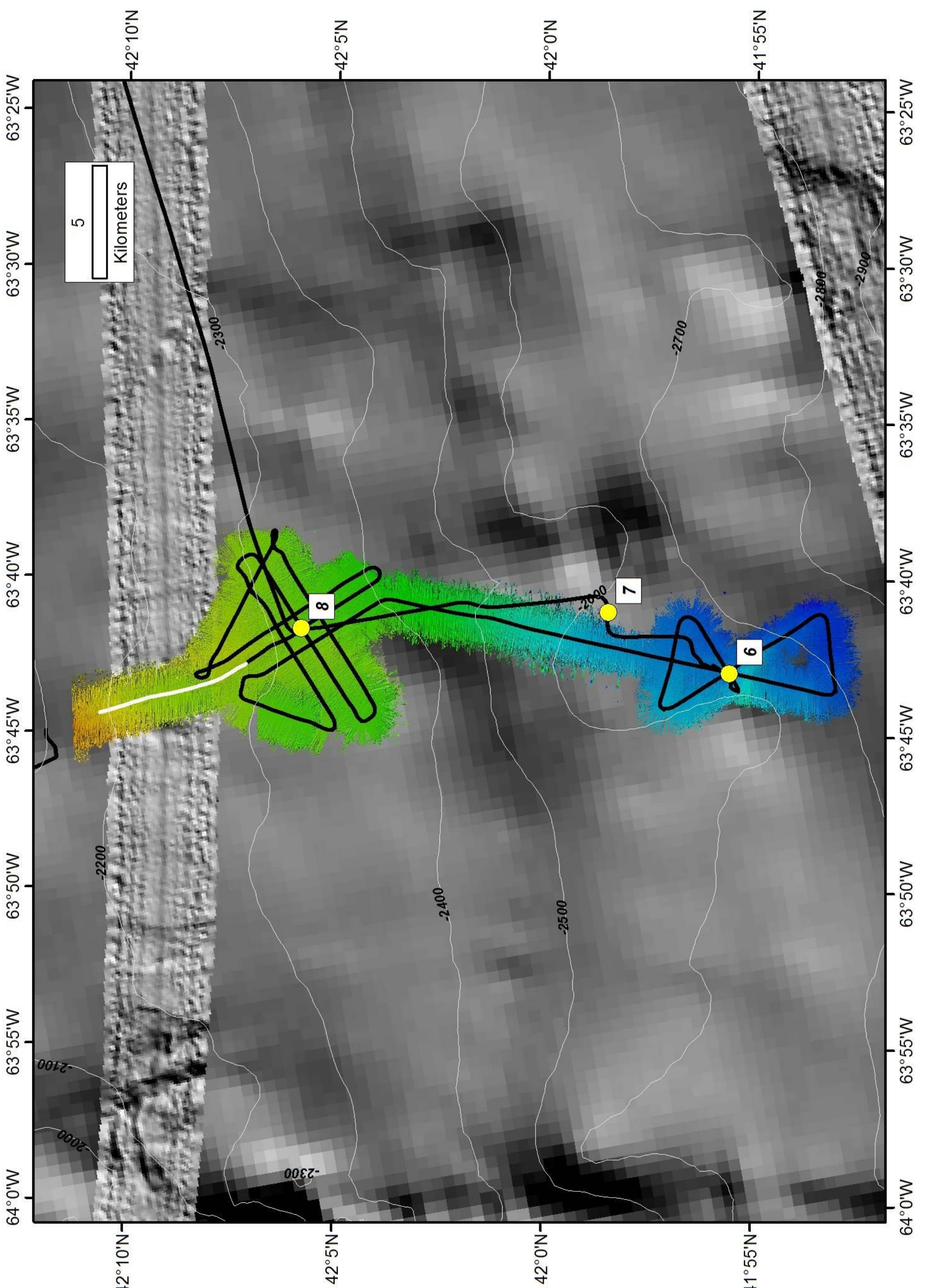

Figure 9.1.3- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

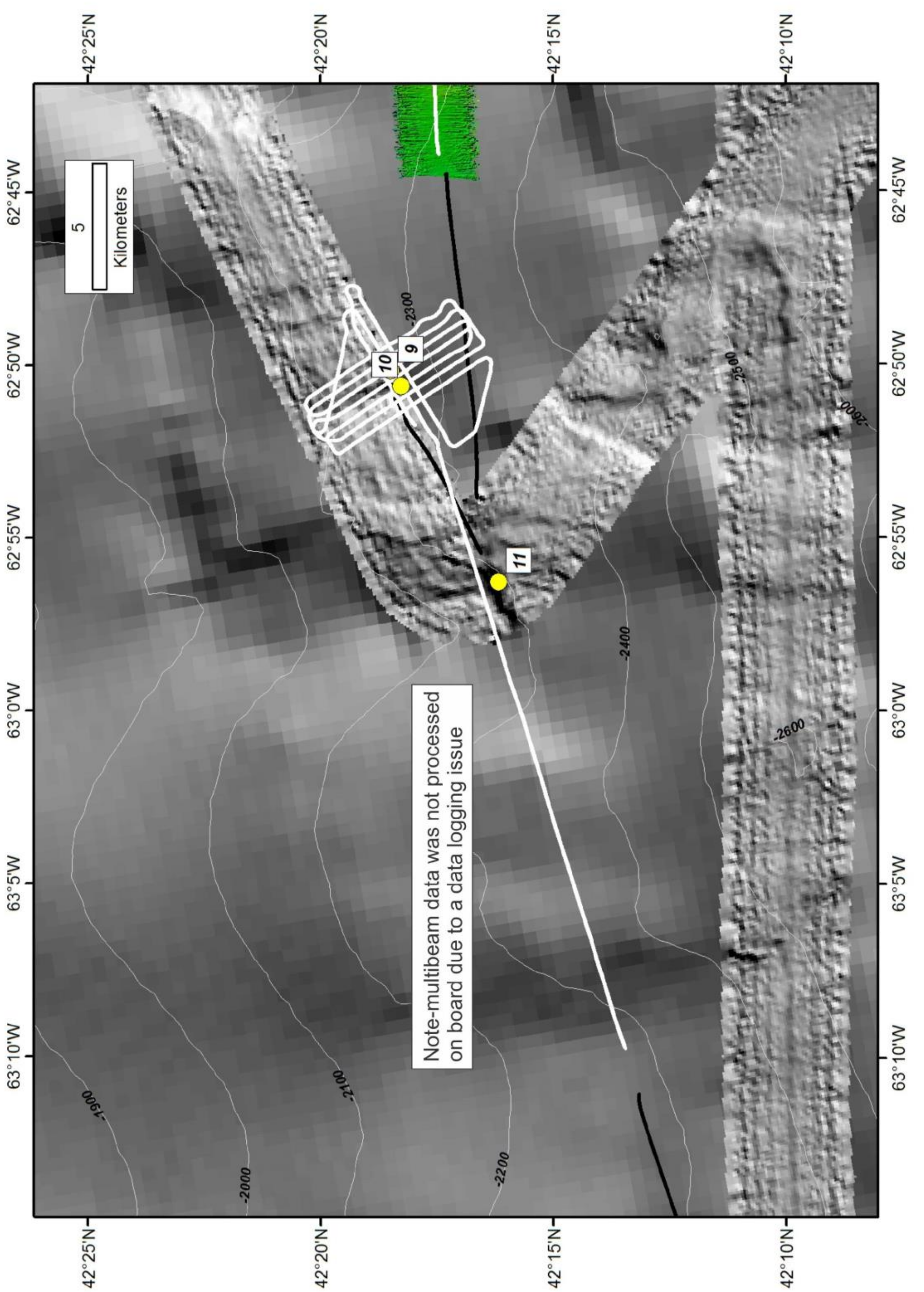

Figure 9.1.4- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

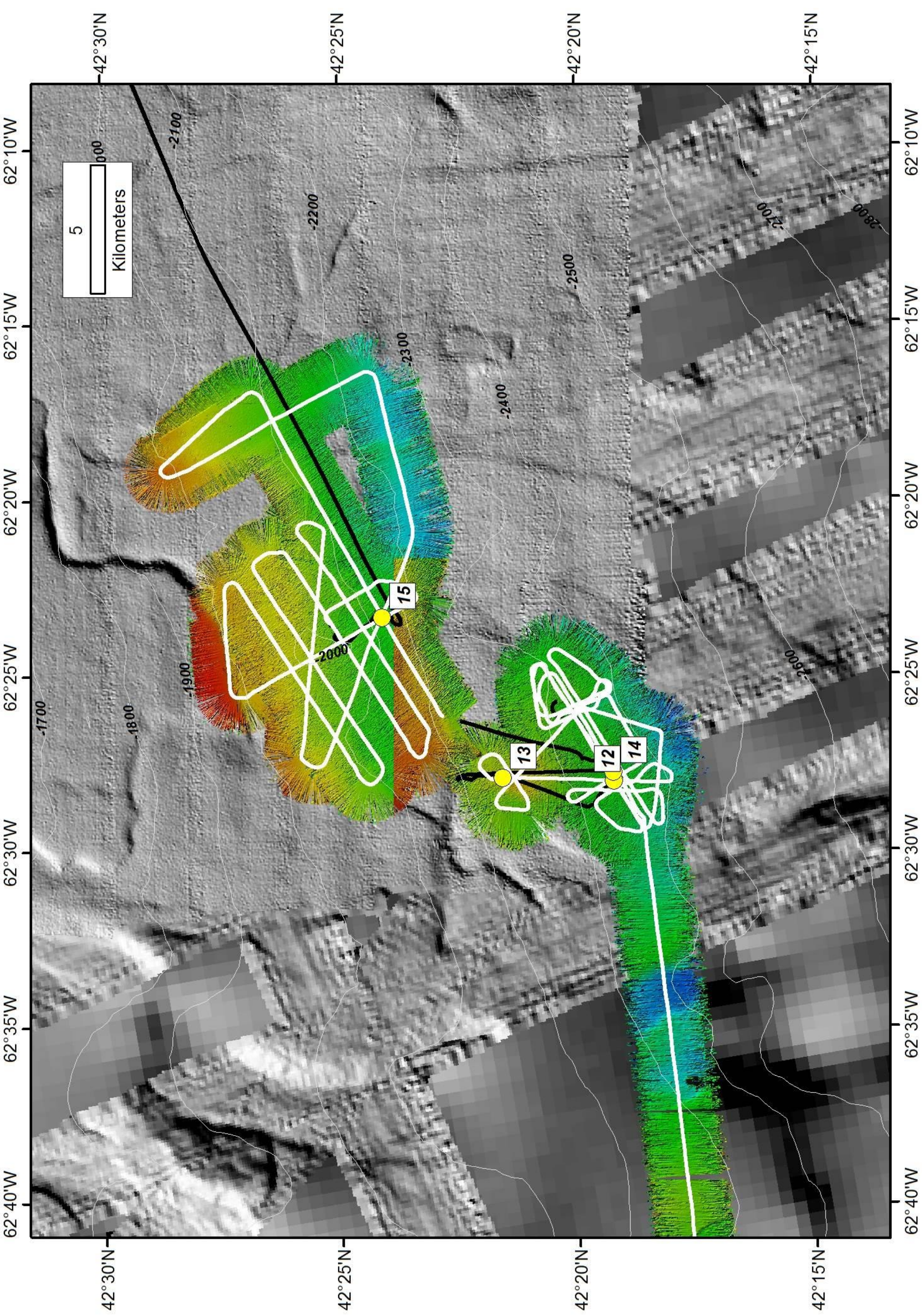

Figure 9.1.5- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

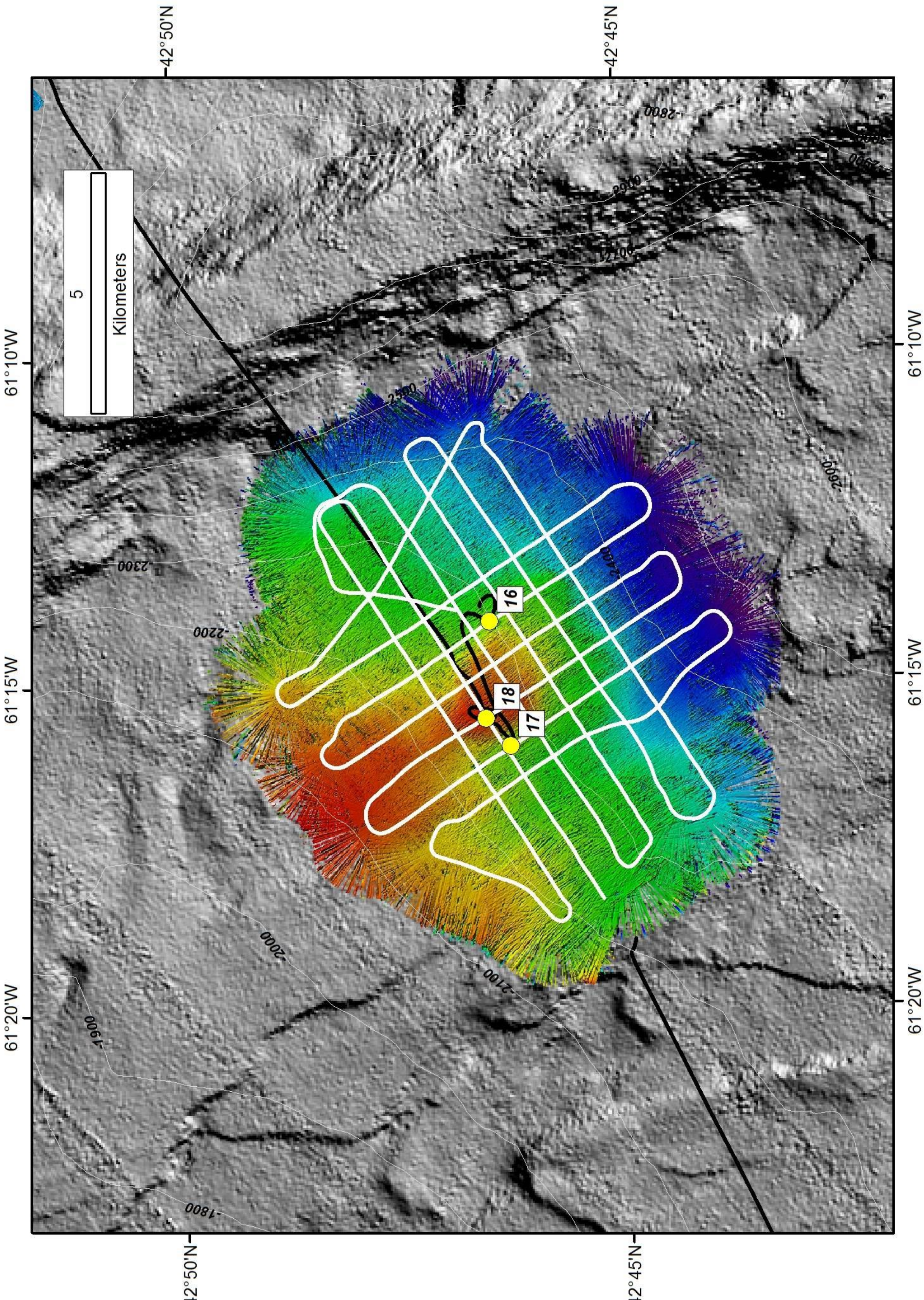

Figure 9.1.6- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

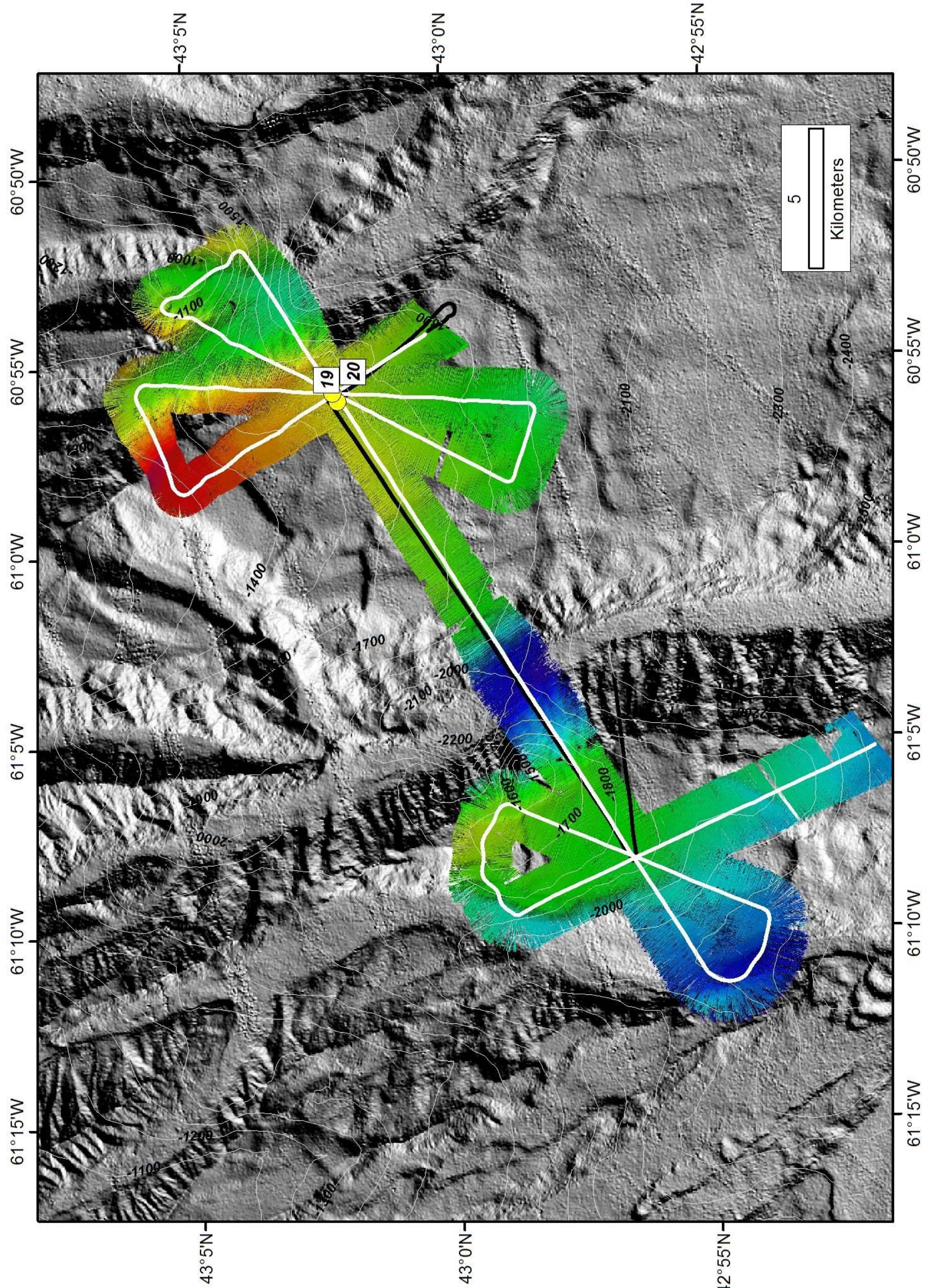

Figure 9.1.7- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

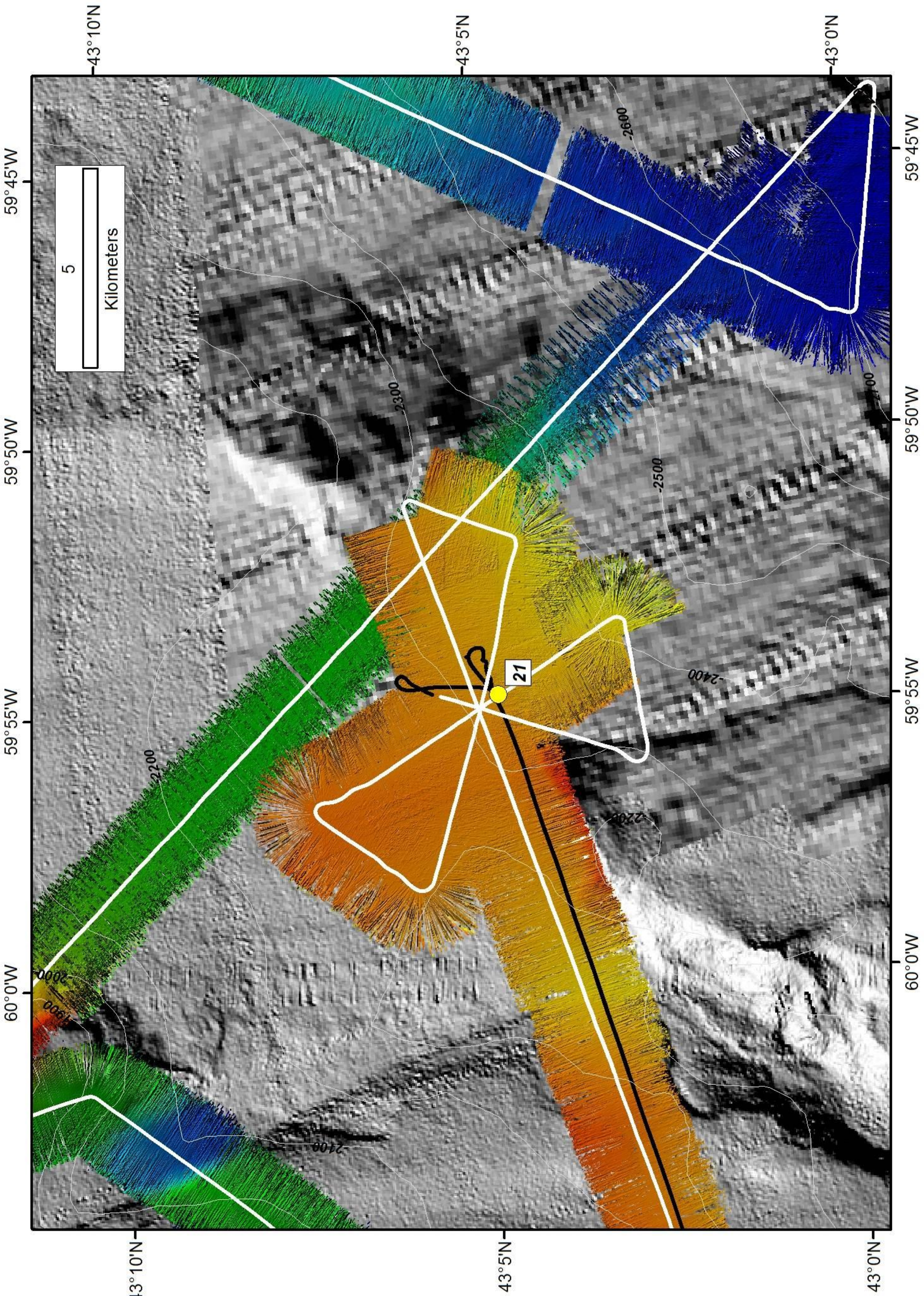

Figure 9.1.8- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

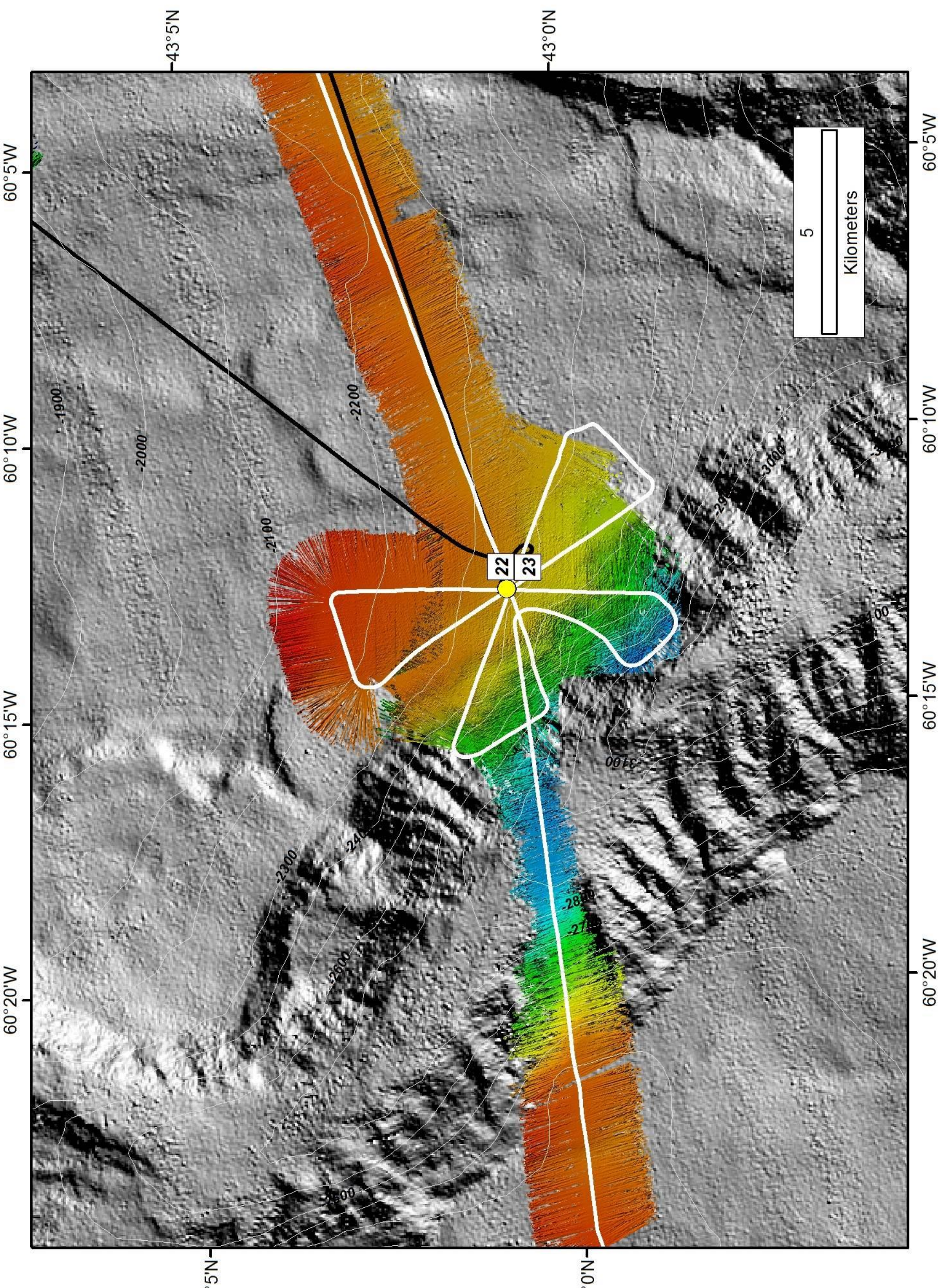

Figure 9.1.9- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

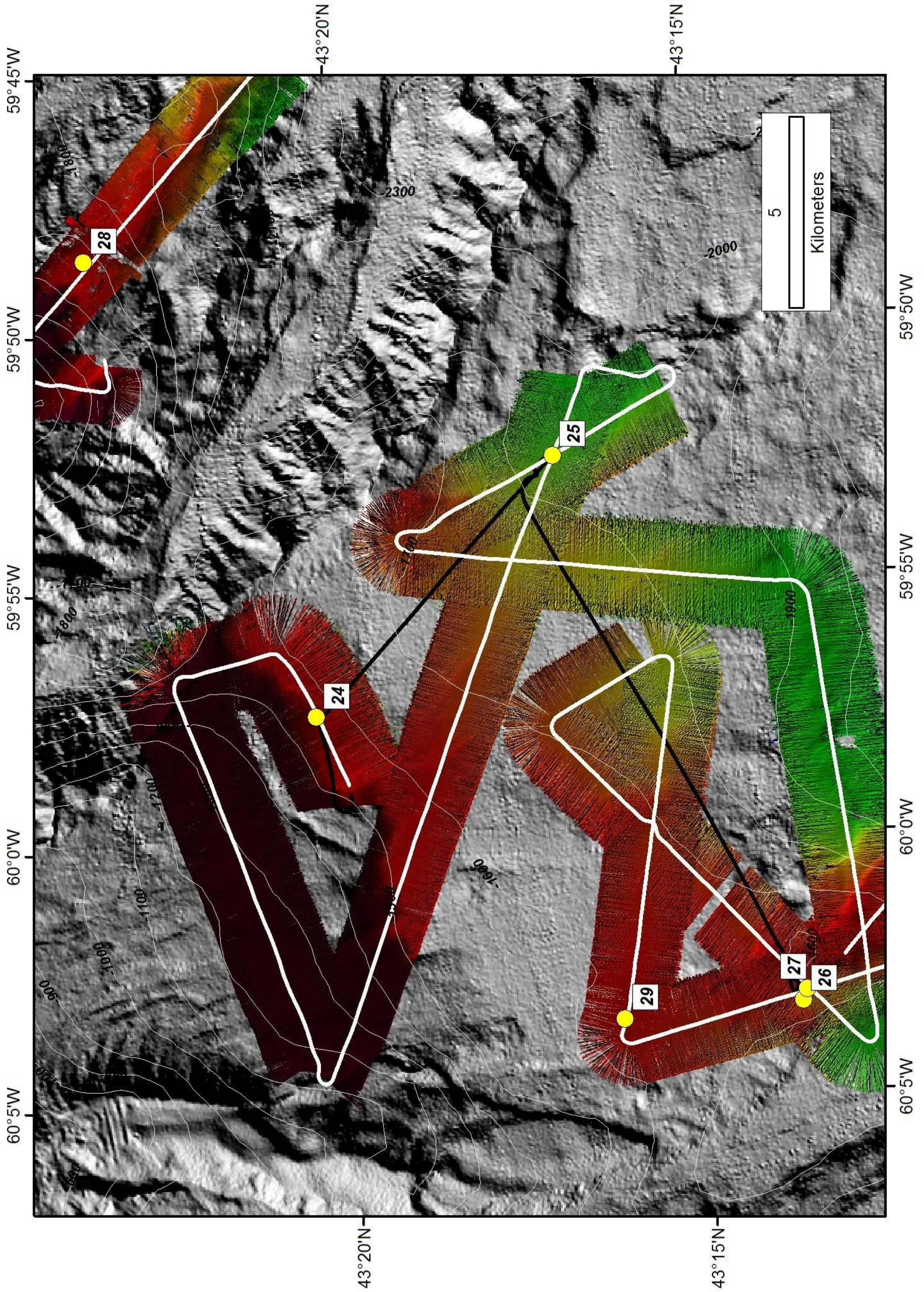

Figure 9.1.10- Data acquired during Hudson 2015-018. The yellow circles are the sample locations, the black lines show Knudesn 3.5 kHz coverage, the white lines show Huntec DTS coverage, and the coloured bathymetry show new multibeam data coverage.

9.2 High resolution sub-bottom profiler data over core sites

The following figures display the high resolution sub-bottom profiler data over the cores sites, usually in multiple directions per core.

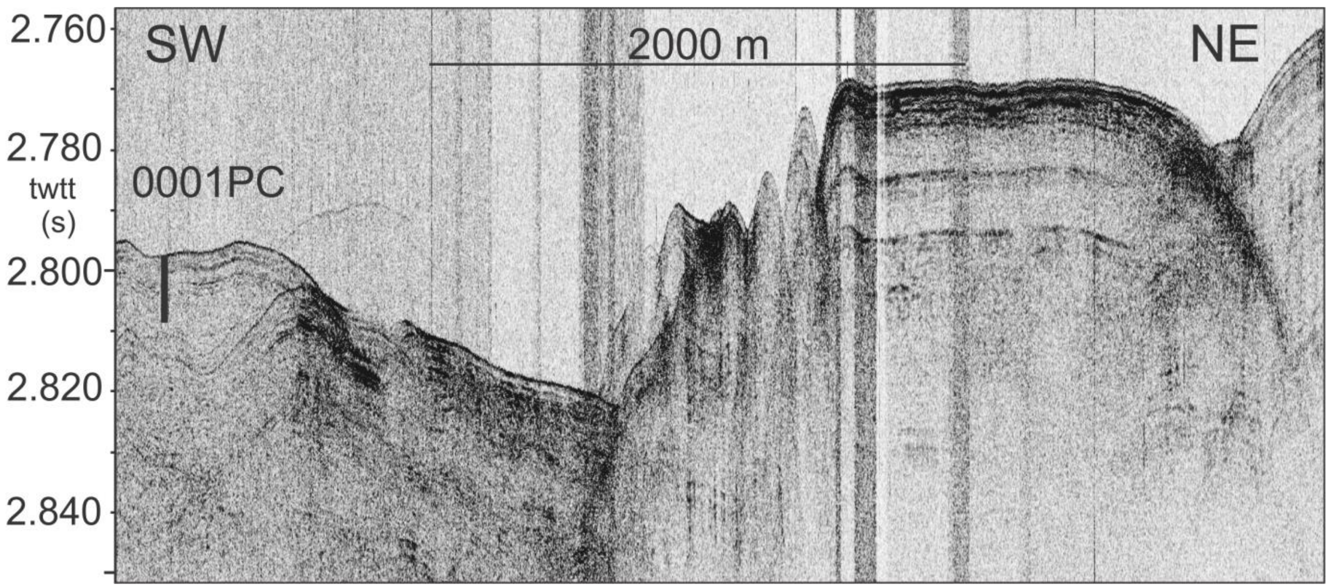

Figure 9.2.1- High resolution sub-bottom profiler data over core 0001.

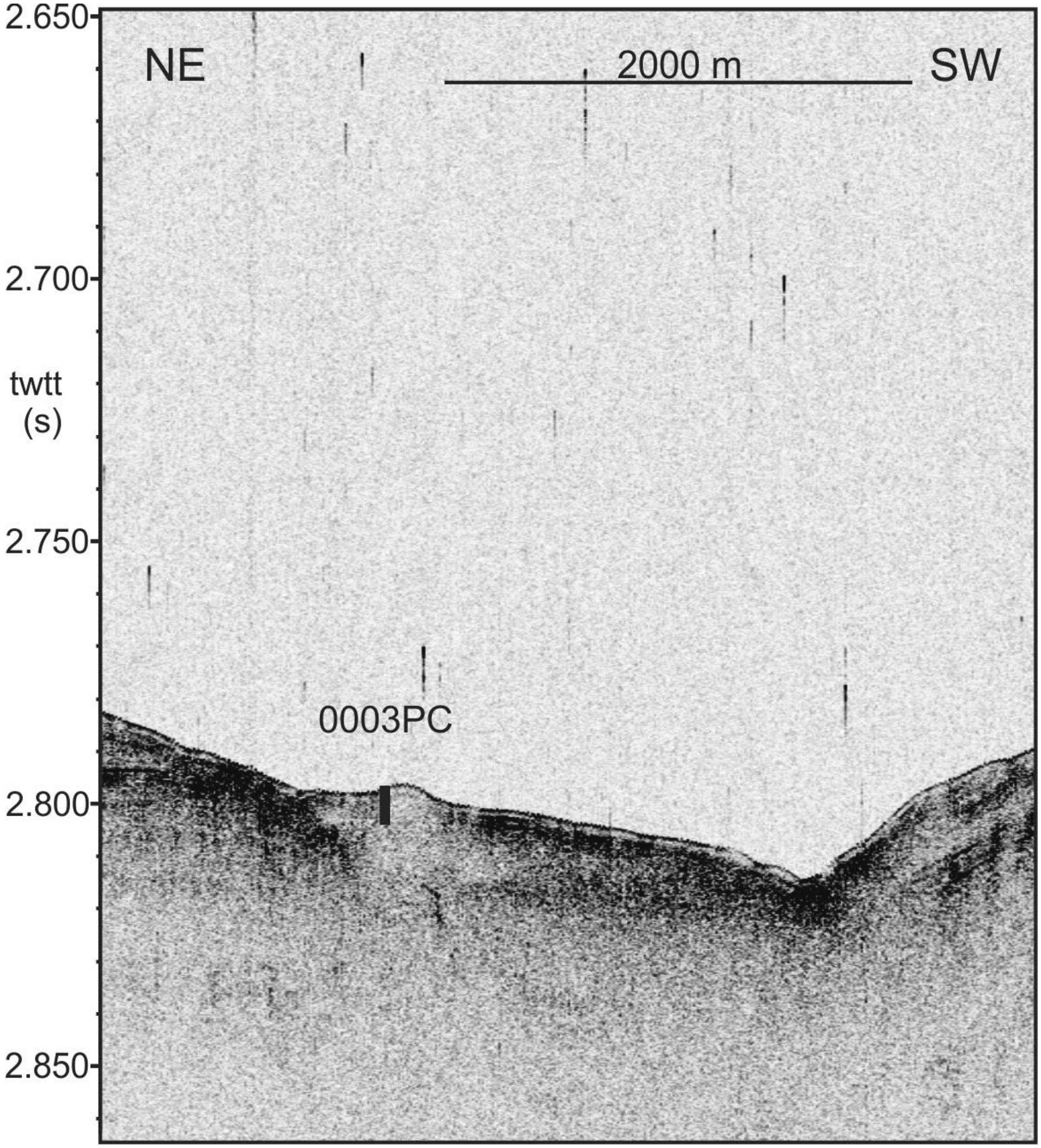

Figure 9.2.2- High resolution sub-bottom profiler data over core 0003.

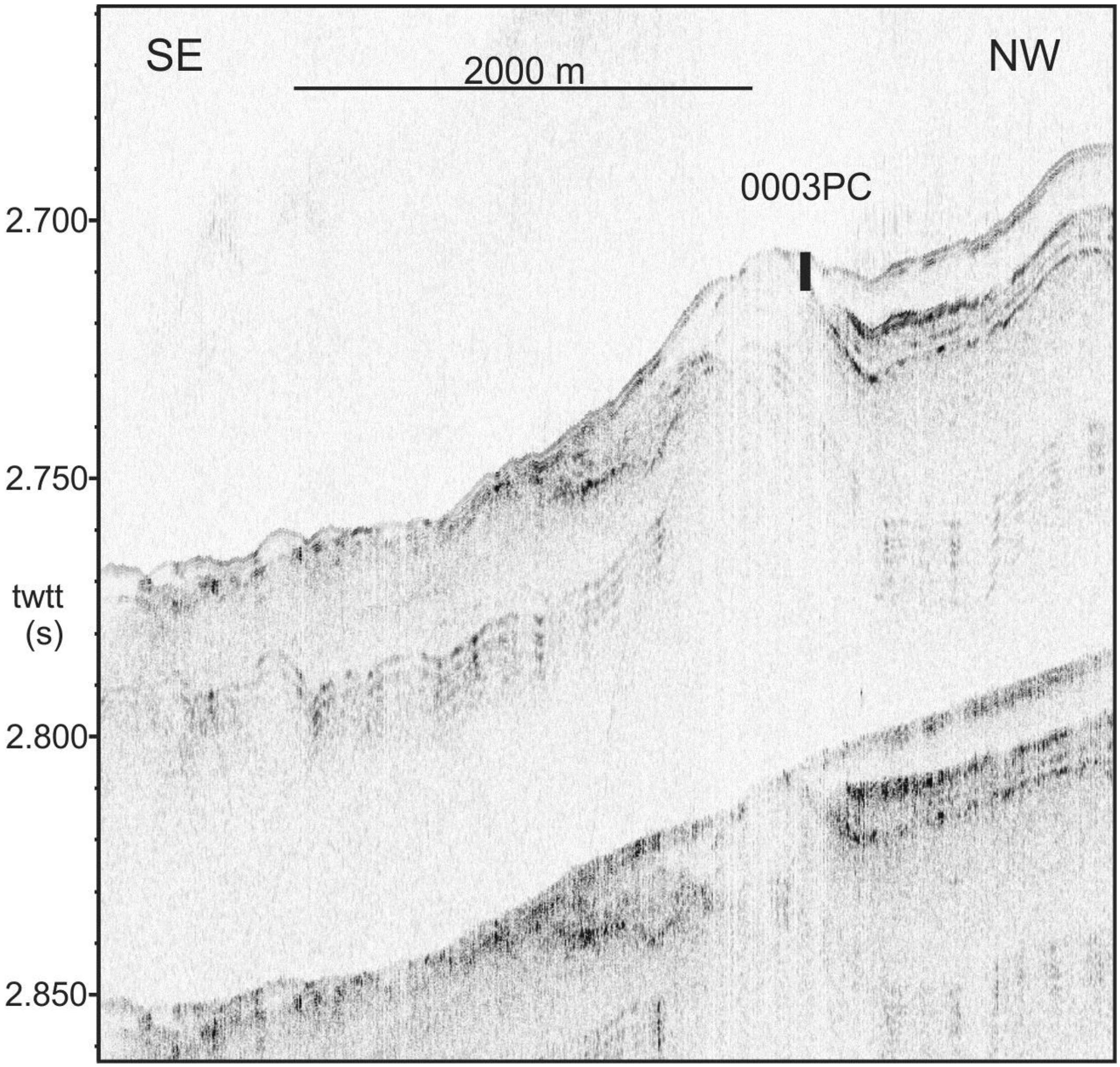

Figure 9.2.3- High resolution sub-bottom profiler data over core 0003.

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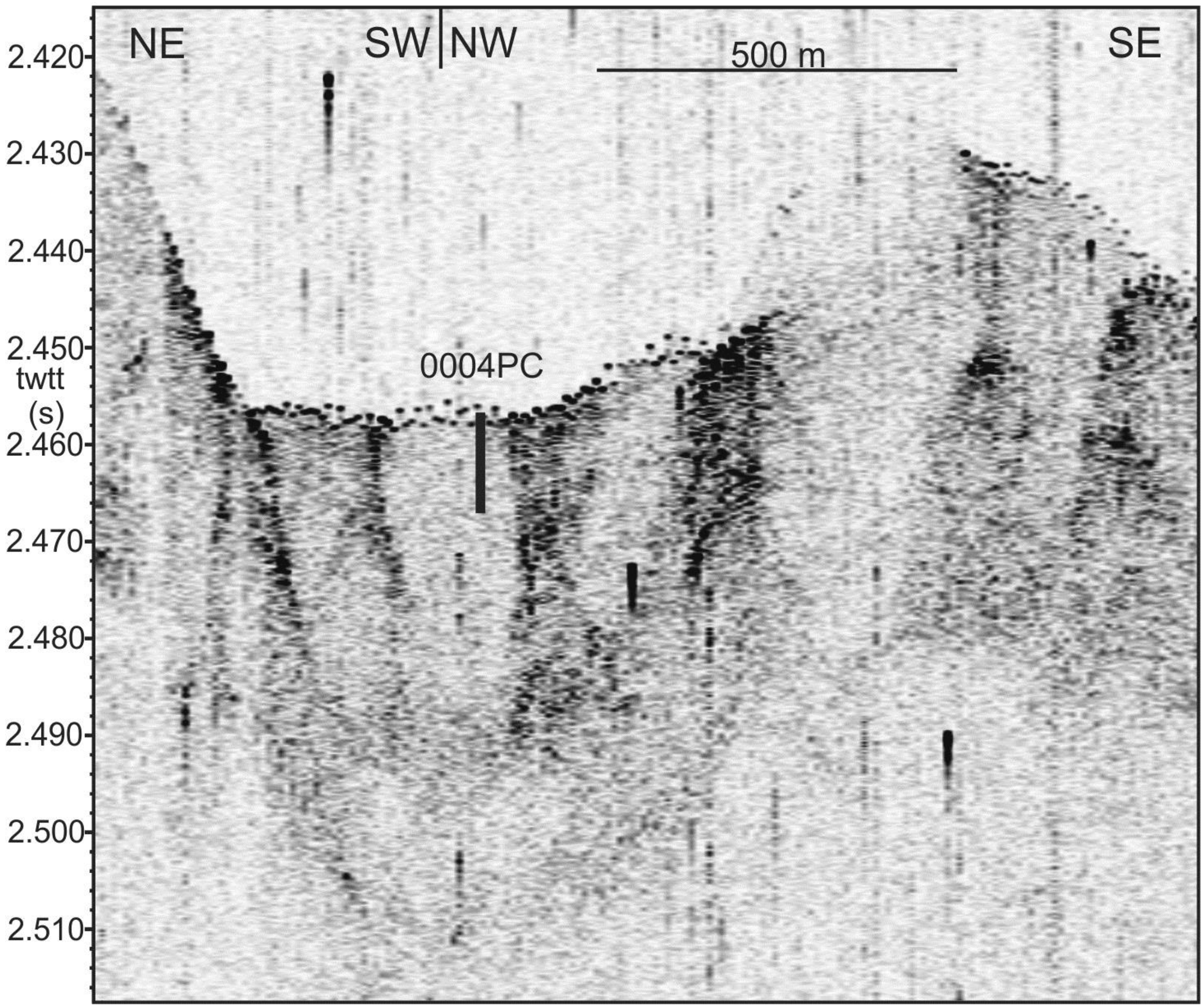

Figure 9.2.4- High resolution sub-bottom profiler data over core 0004.

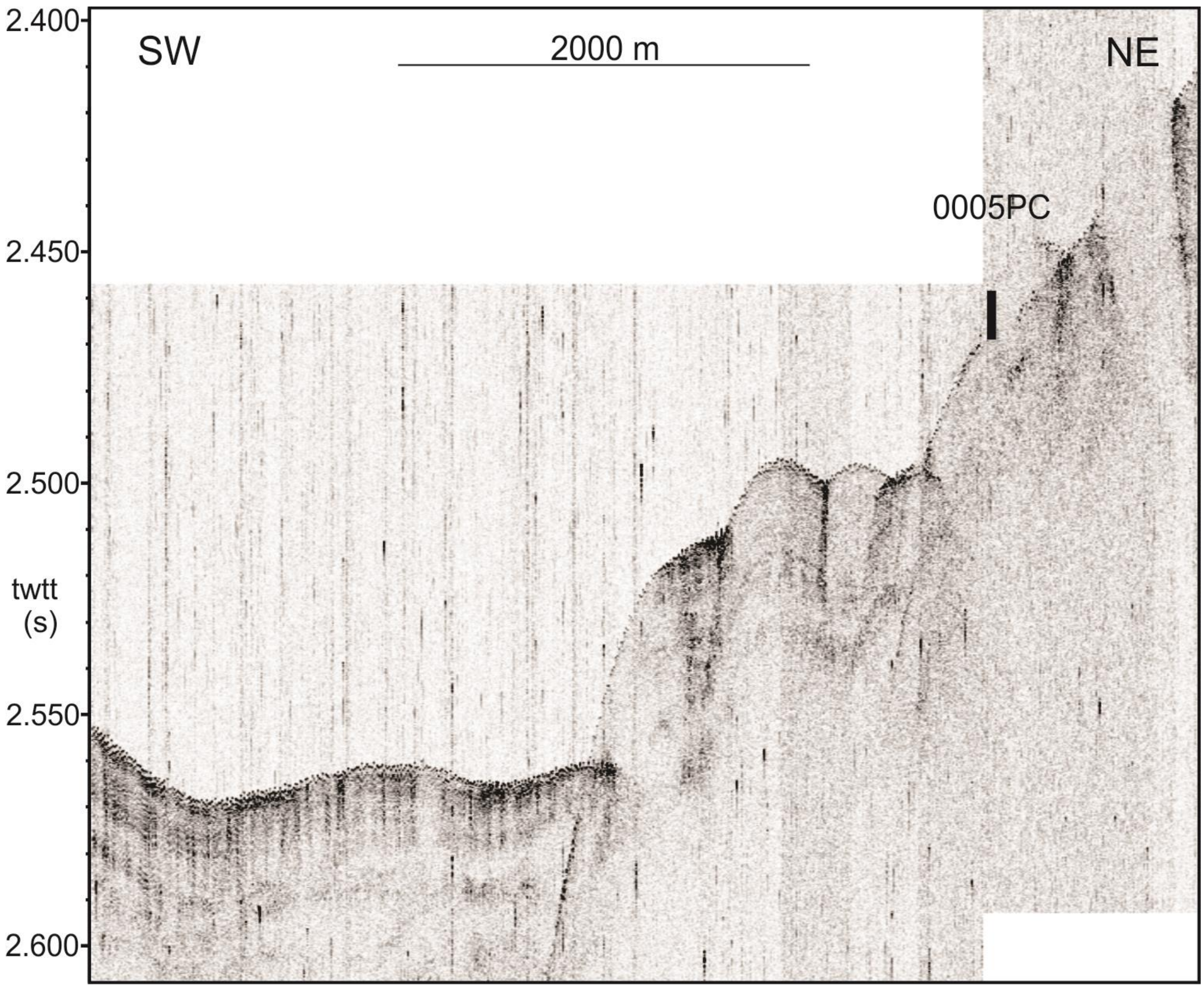

Figure 9.2.5- High resolution sub-bottom profiler data over core 0005.

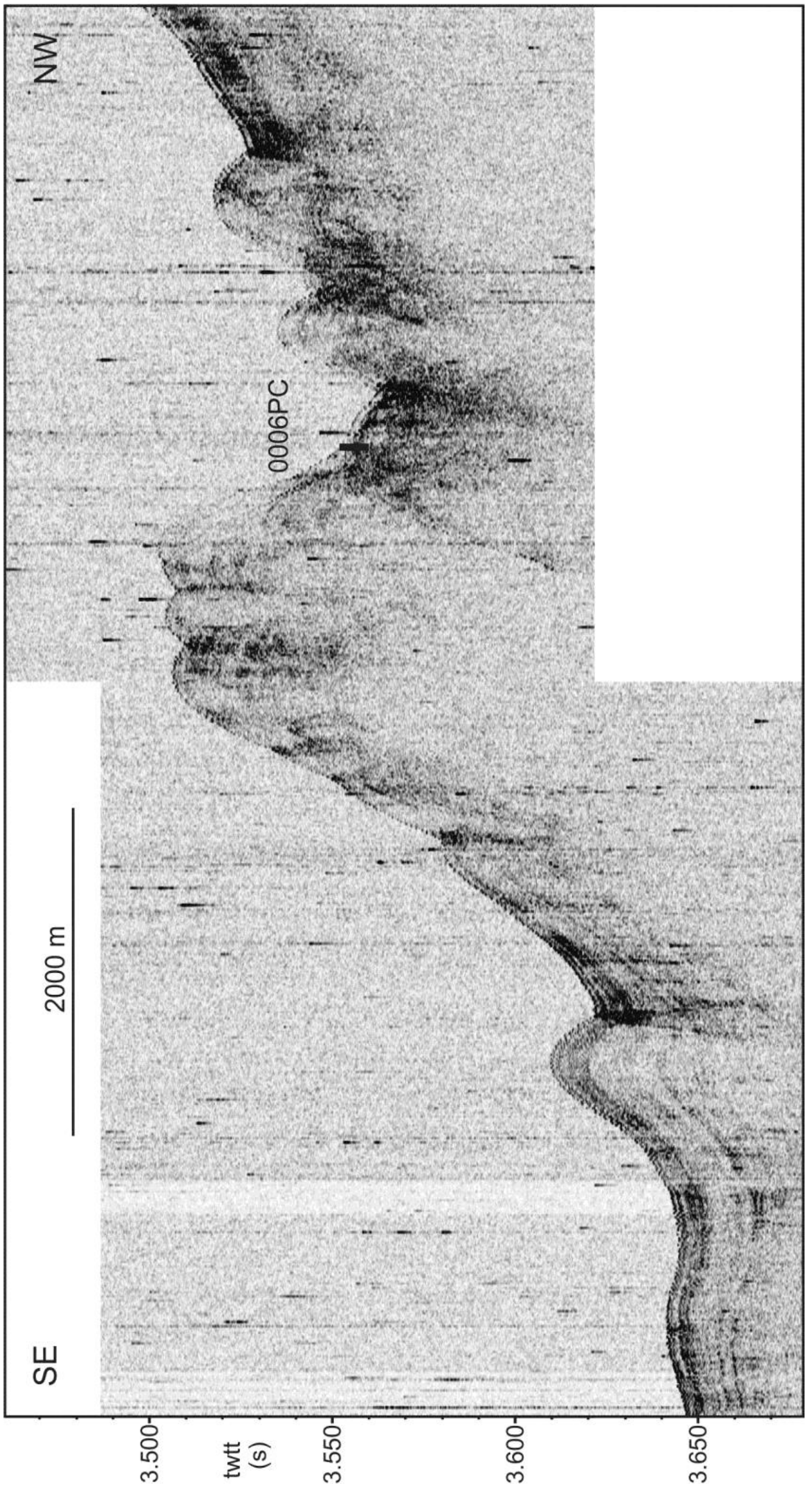

Figure 9.2.6- High resolution sub-bottom profiler data over core 0006.

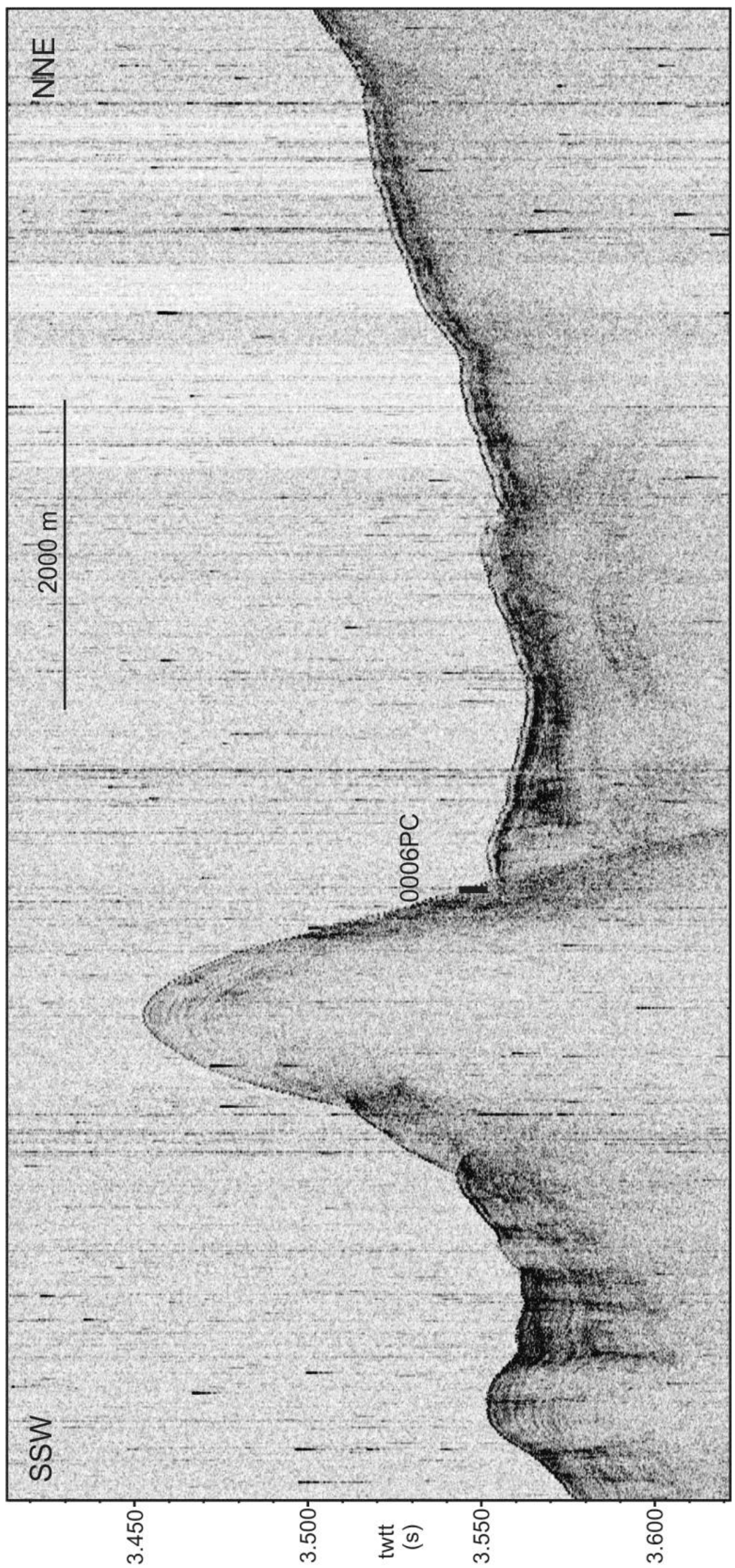

Figure 9.2.7- High resolution sub-bottom profiler data over core 0006.

Figure 9.2.8- High resolution sub-bottom profiler data over core 0006.

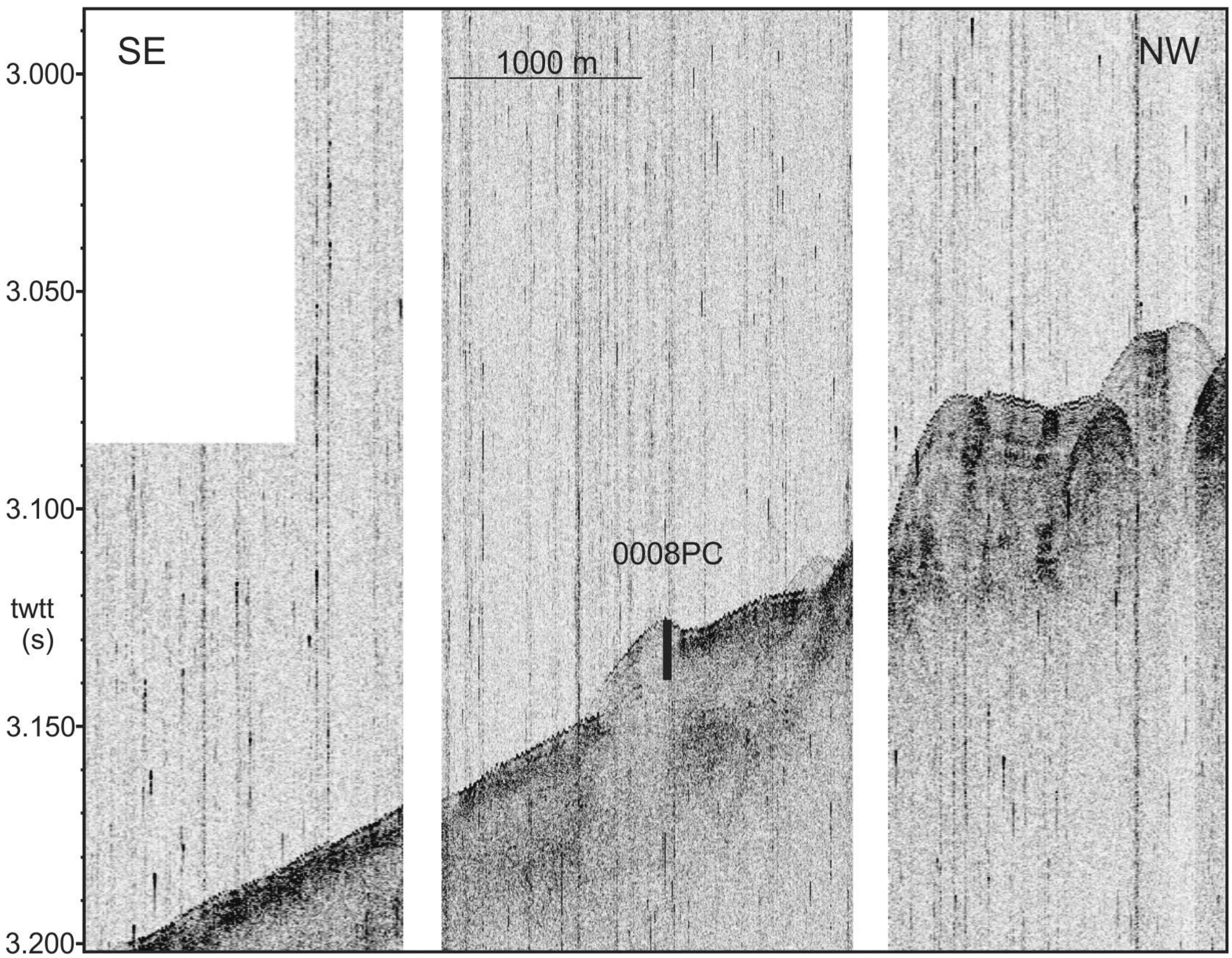

Figure 9.2.9- High resolution sub-bottom profiler data over core 0008.

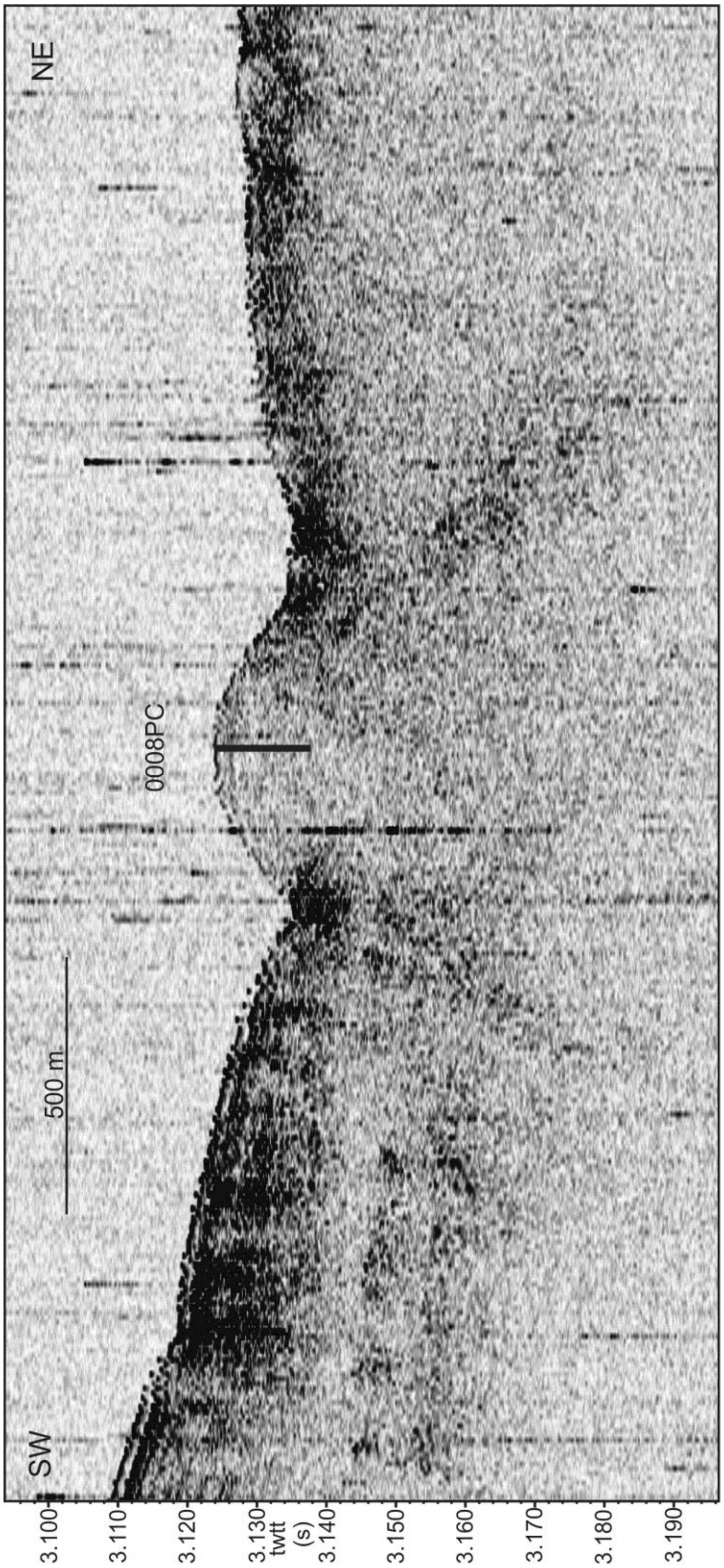

Figure 9.2.10- High resolution sub-bottom profiler data over core 0008.

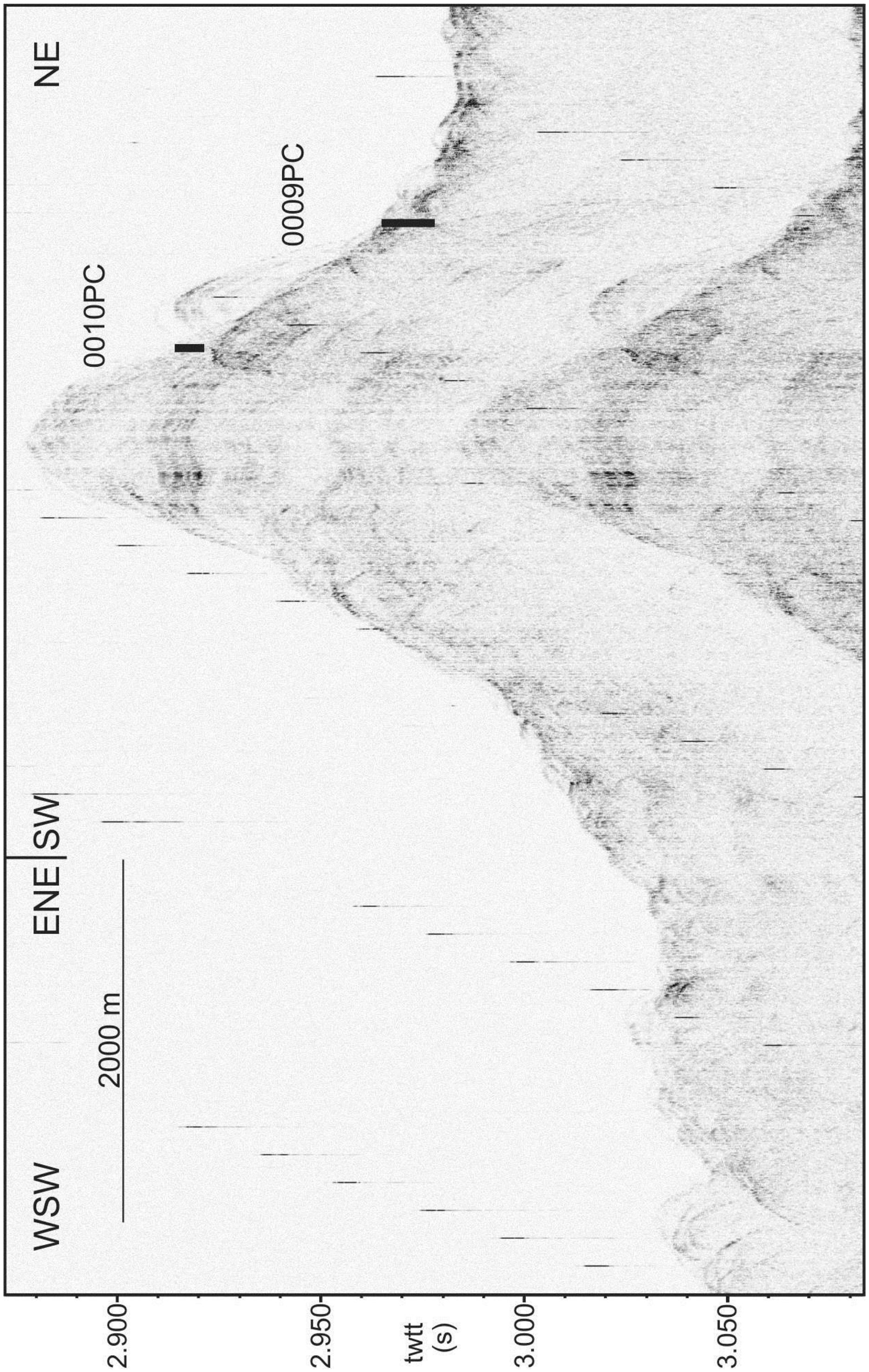

Figure 9.2.11- High resolution sub-bottom profiler data over cores 0009 and 0010.

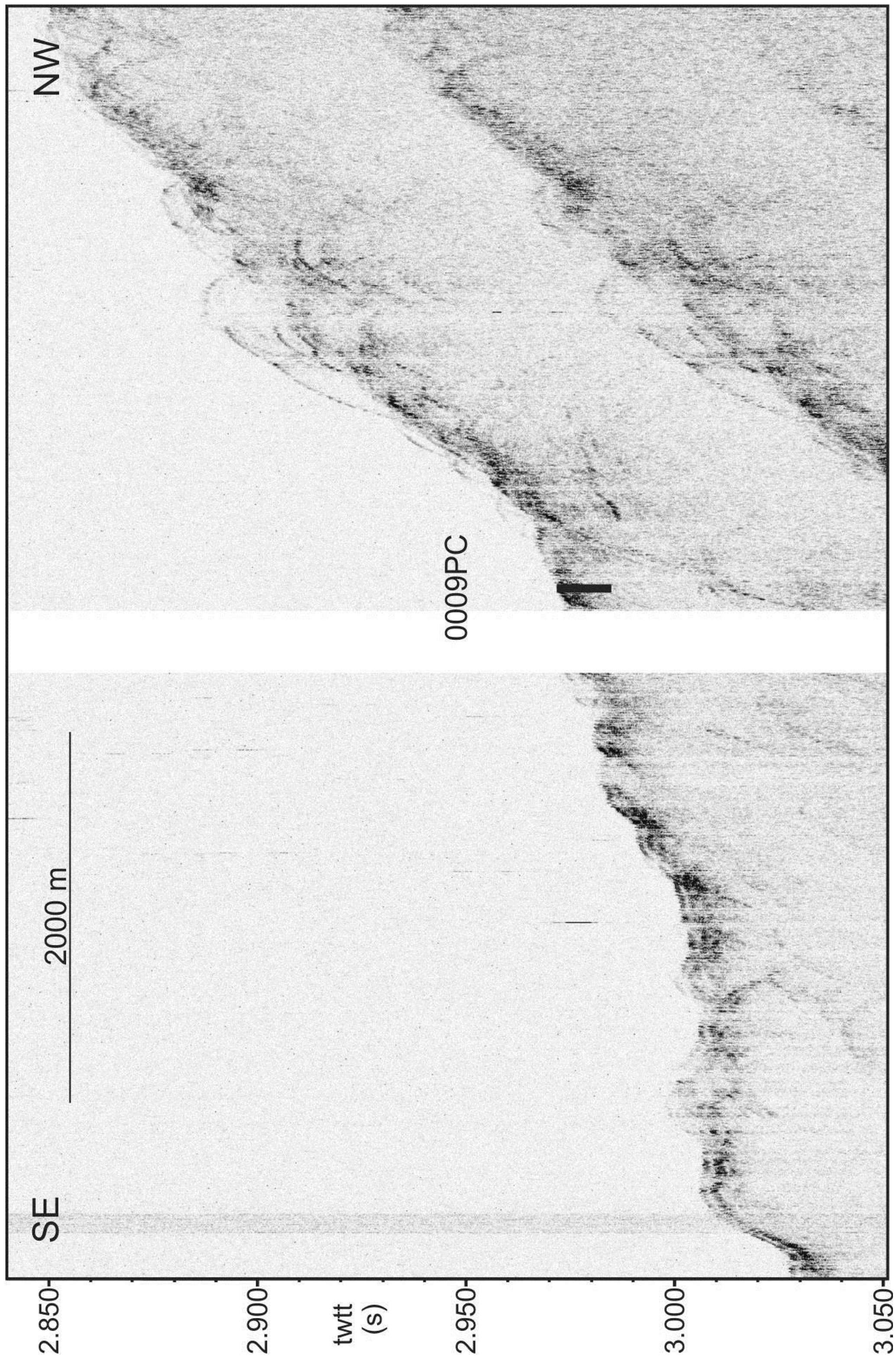

Figure 9.2.12- High resolution sub-bottom profiler data over core 0009.

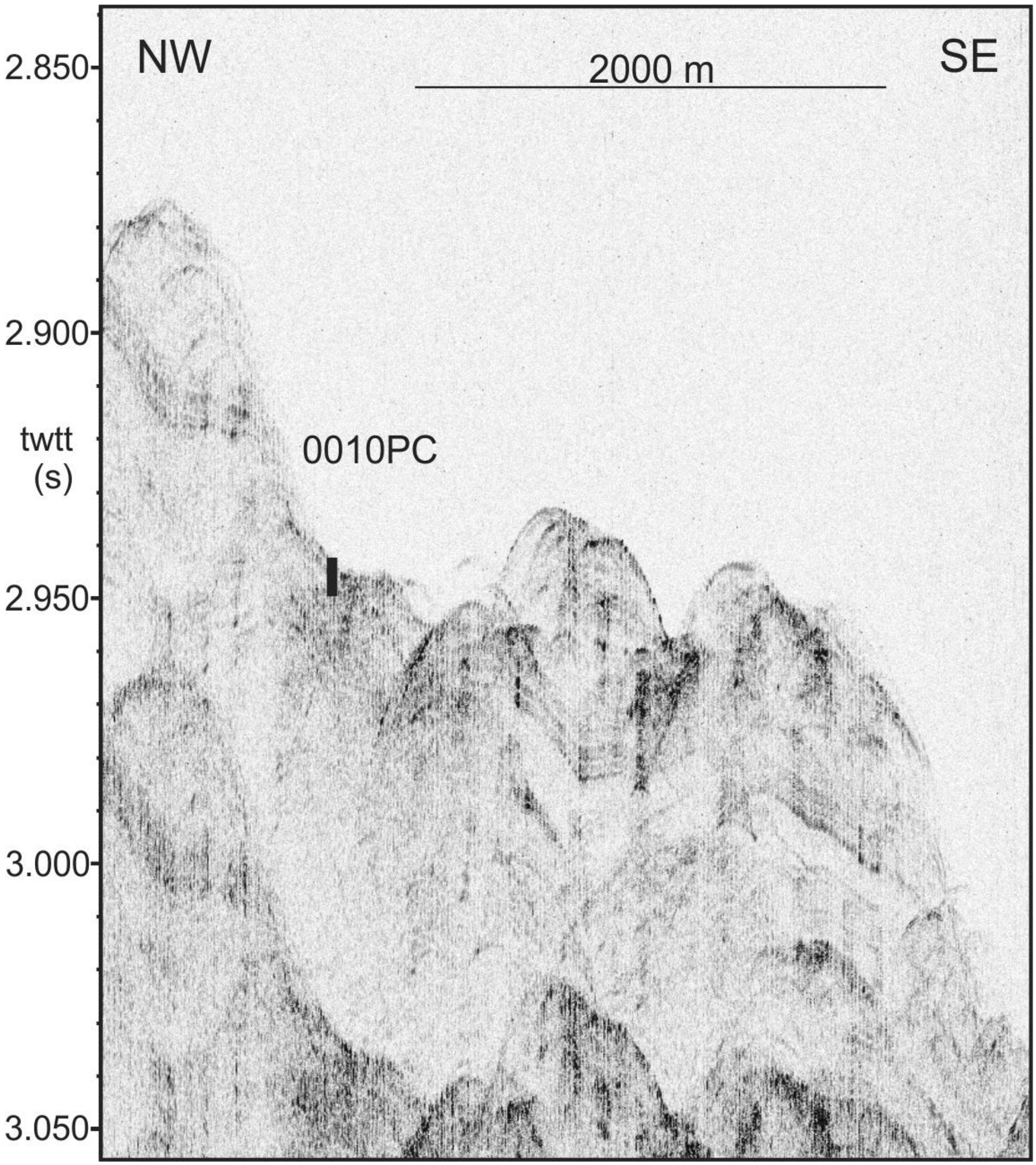

Figure 9.2.13- High resolution sub-bottom profiler data over core 0010.

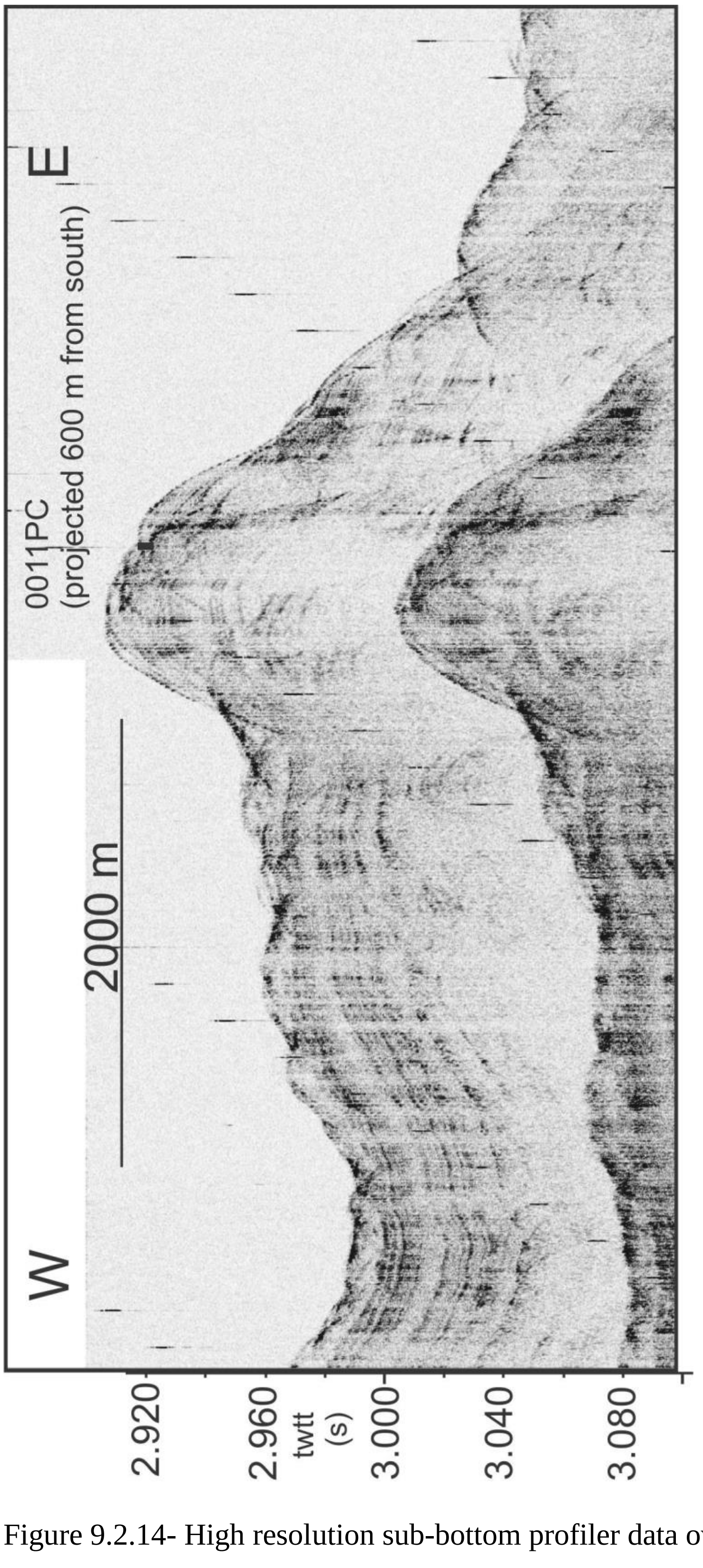

Figure 9.2.14- High resolution sub-bottom profiler data over core 0011.

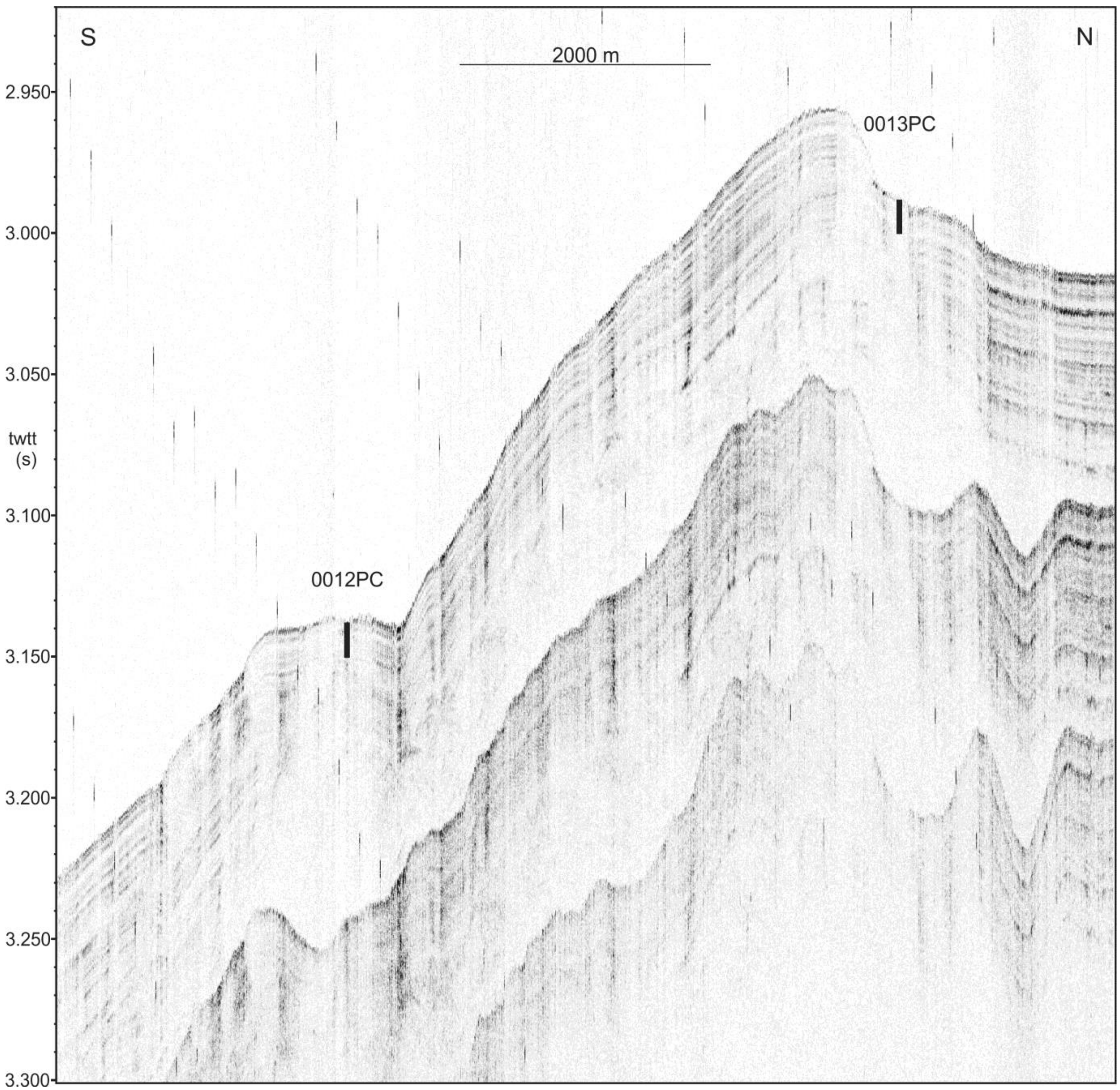

Figure 9.2.15- High resolution sub-bottom profiler data over core 0013.

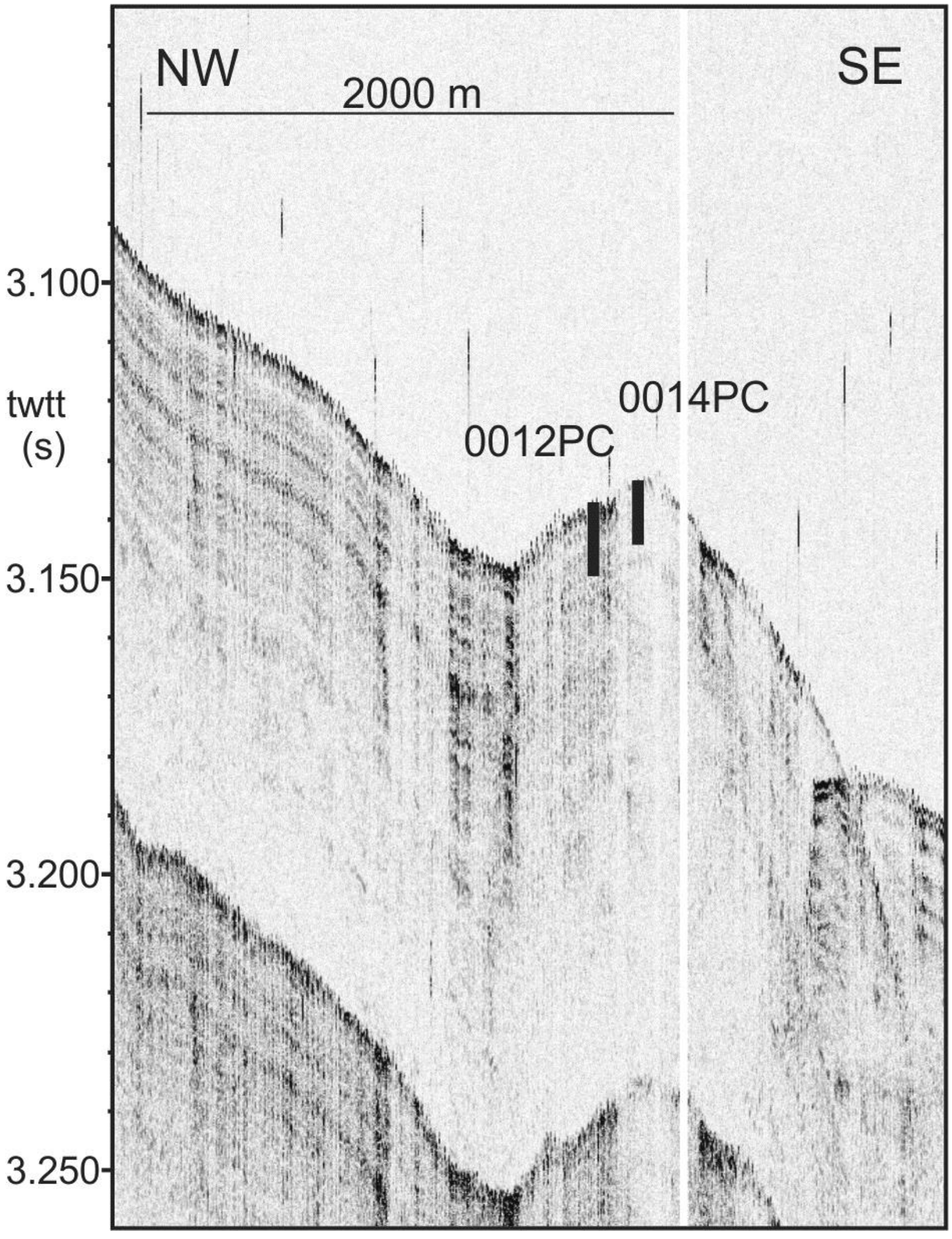

Figure 9.2.16- High resolution sub-bottom profiler data over cores 0012 and 0014.

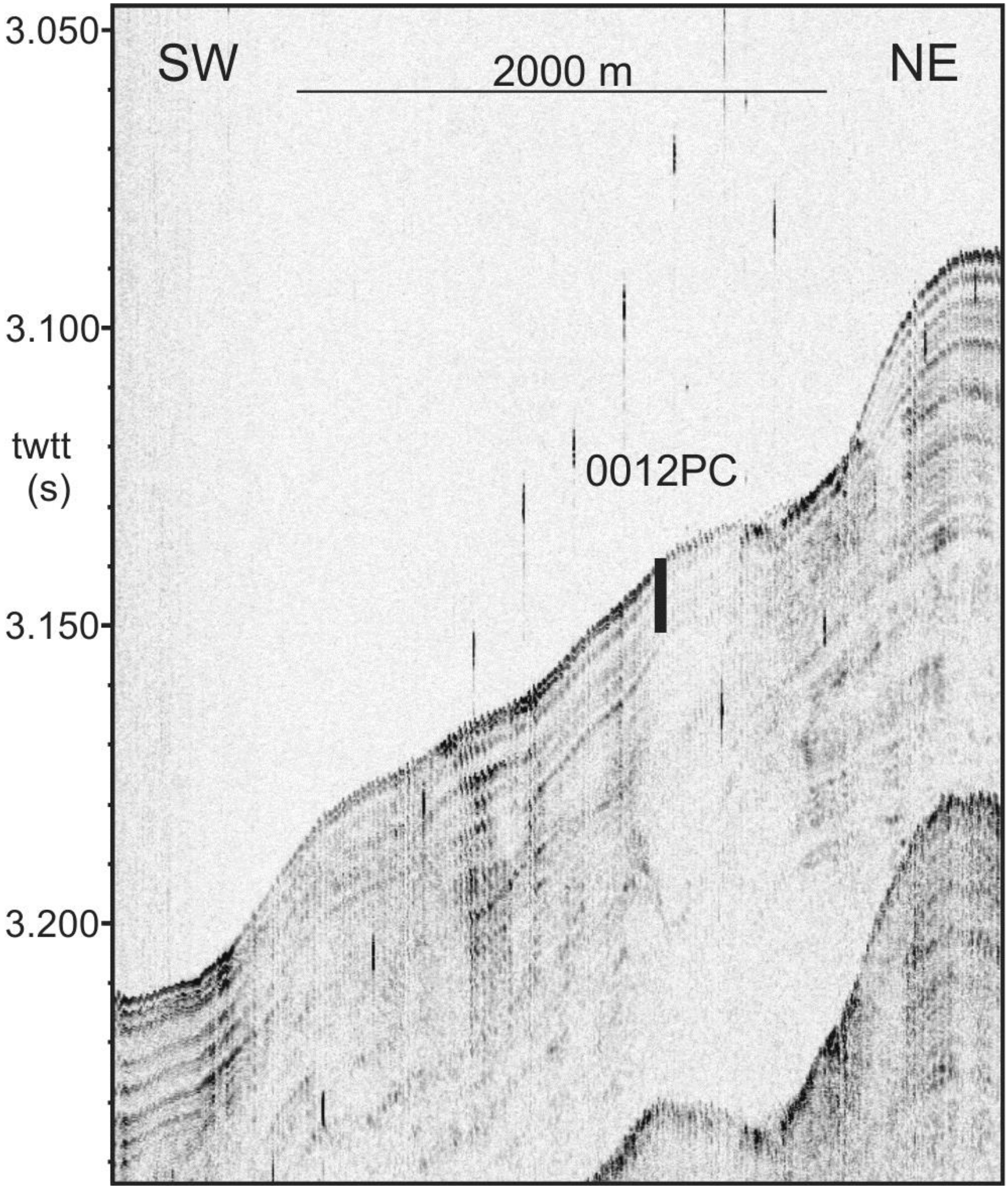

Figure 9.2.17- High resolution sub-bottom profiler data over core 0012.

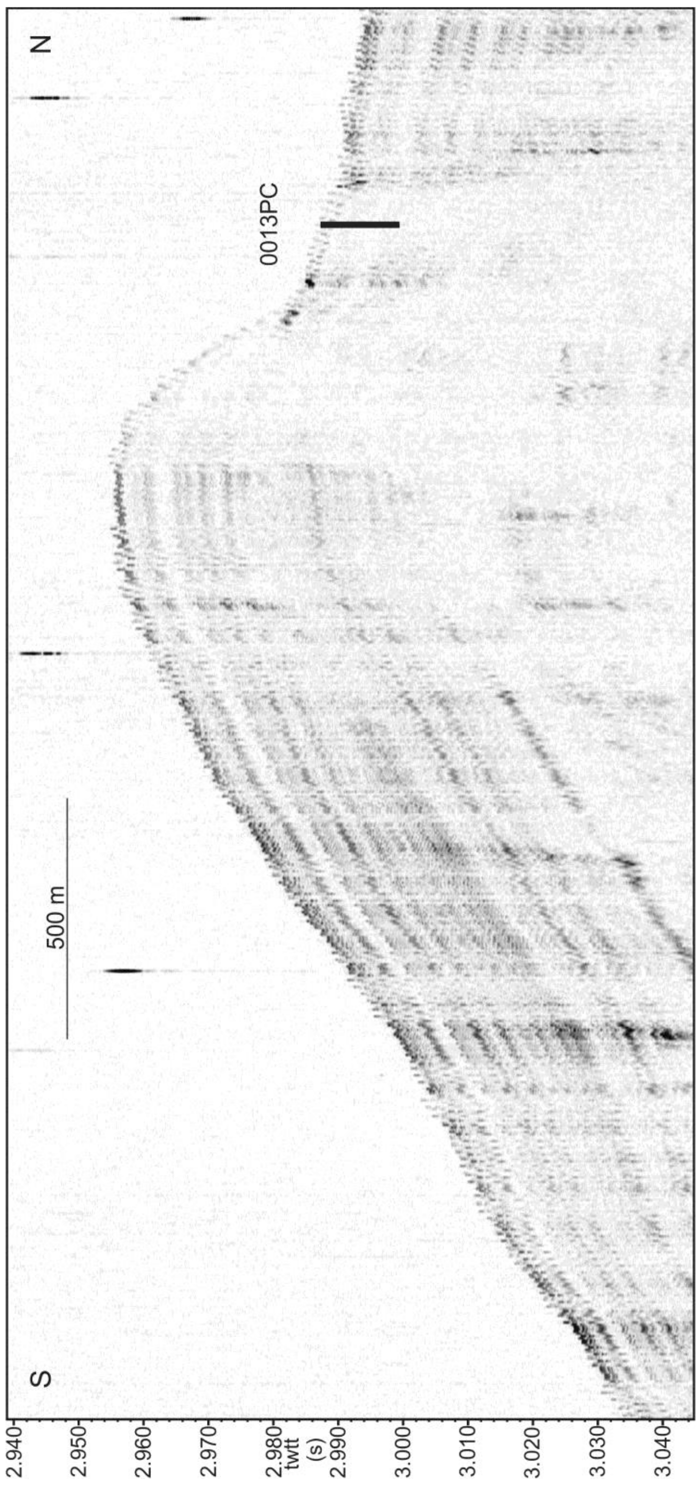

Figure 9.2.18- High resolution sub-bottom profiler data over core 0013.

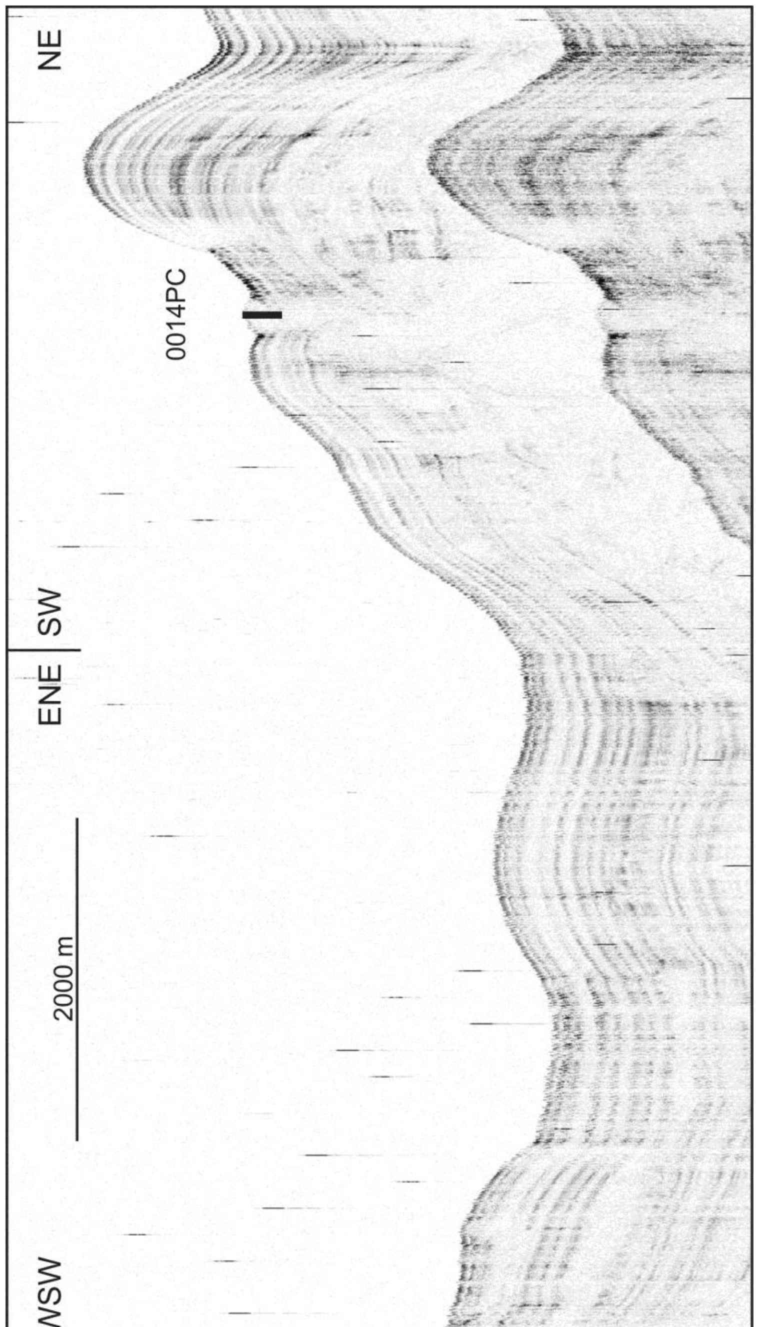

Figure 9.2.19- High resolution sub-bottom profiler data over core 0014.

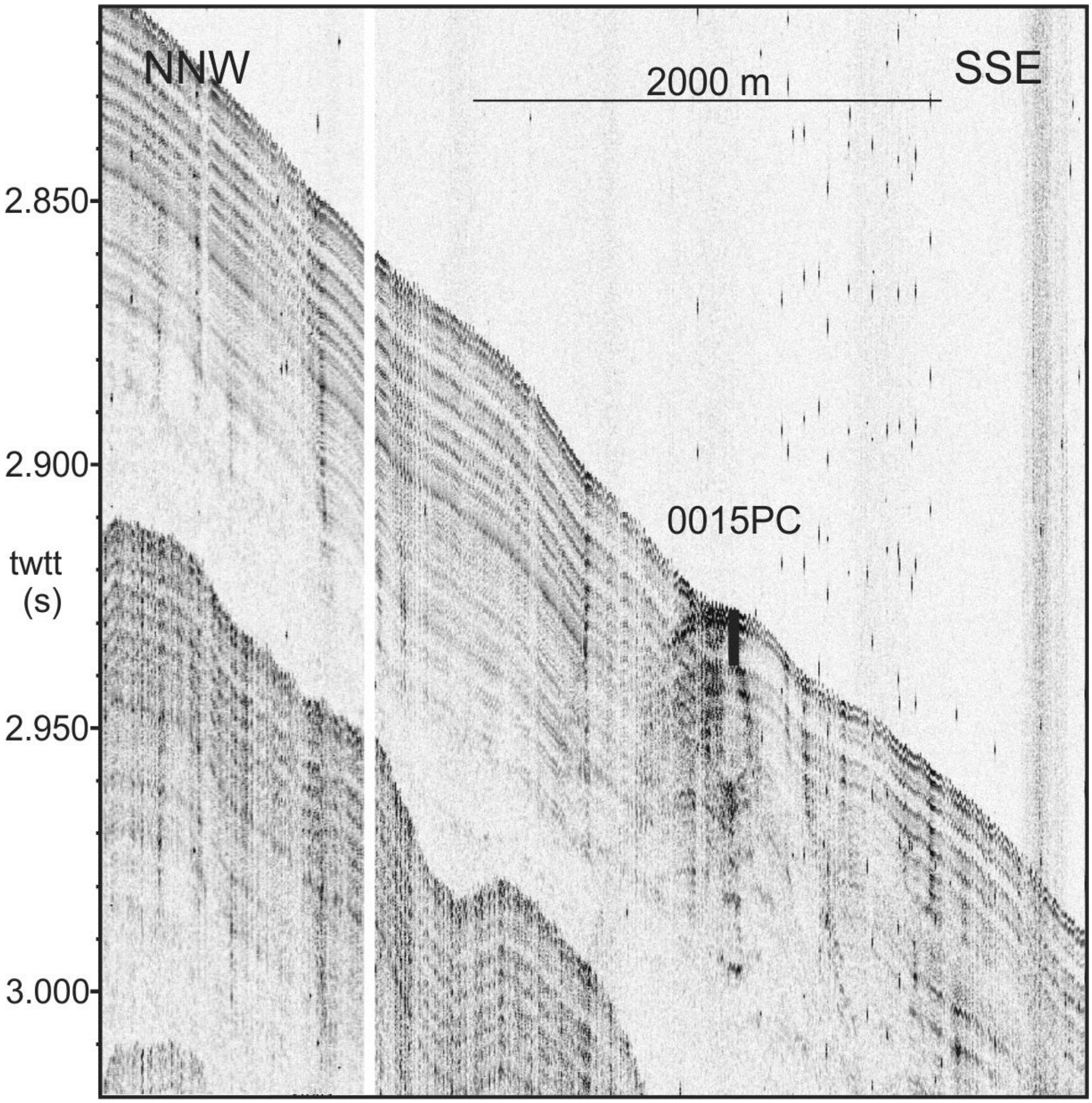

Figure 9.2.20- High resolution sub-bottom profiler data over core 0015.

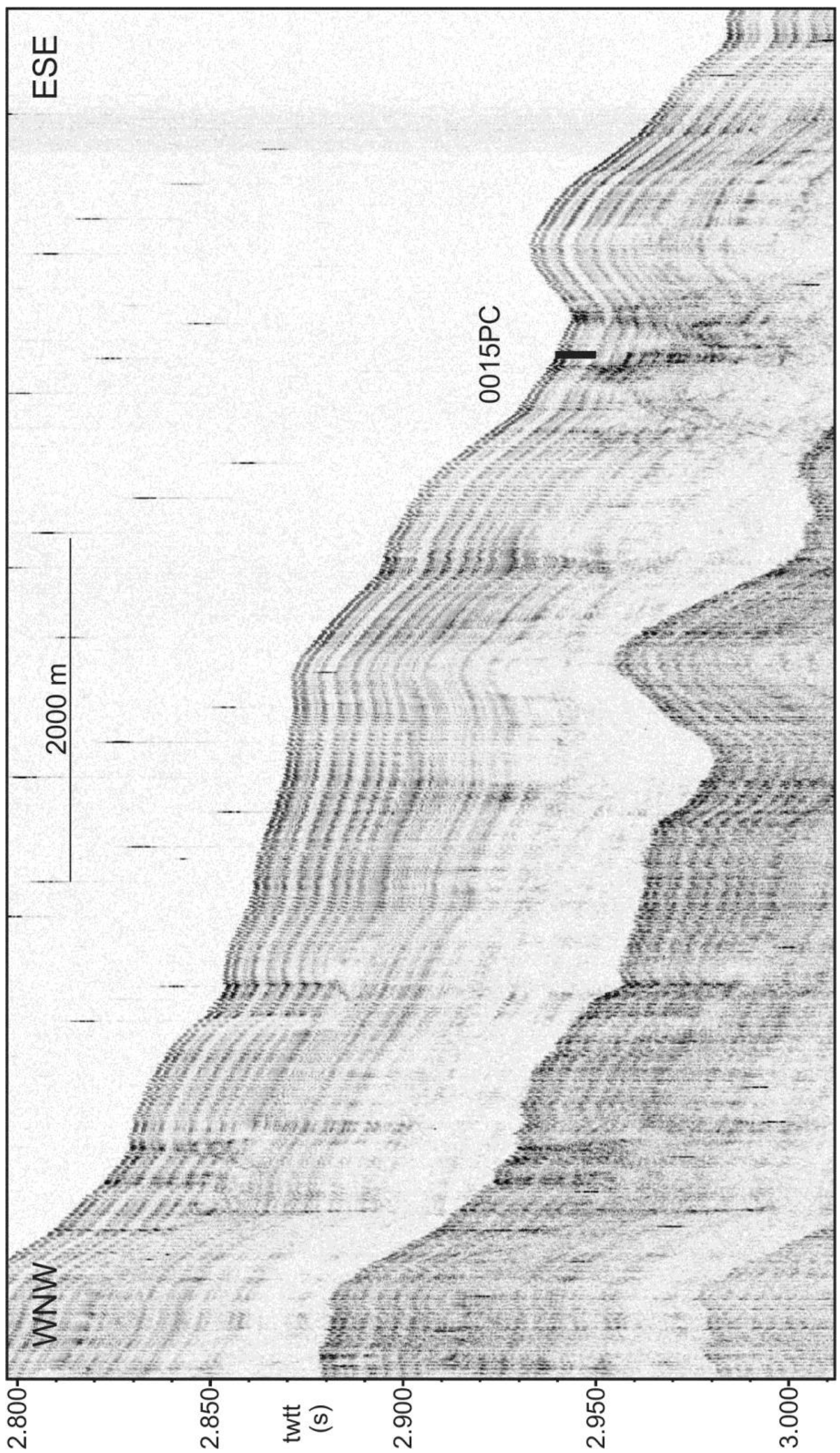

Figure 9.2.21- High resolution sub-bottom profiler data over core 0015.

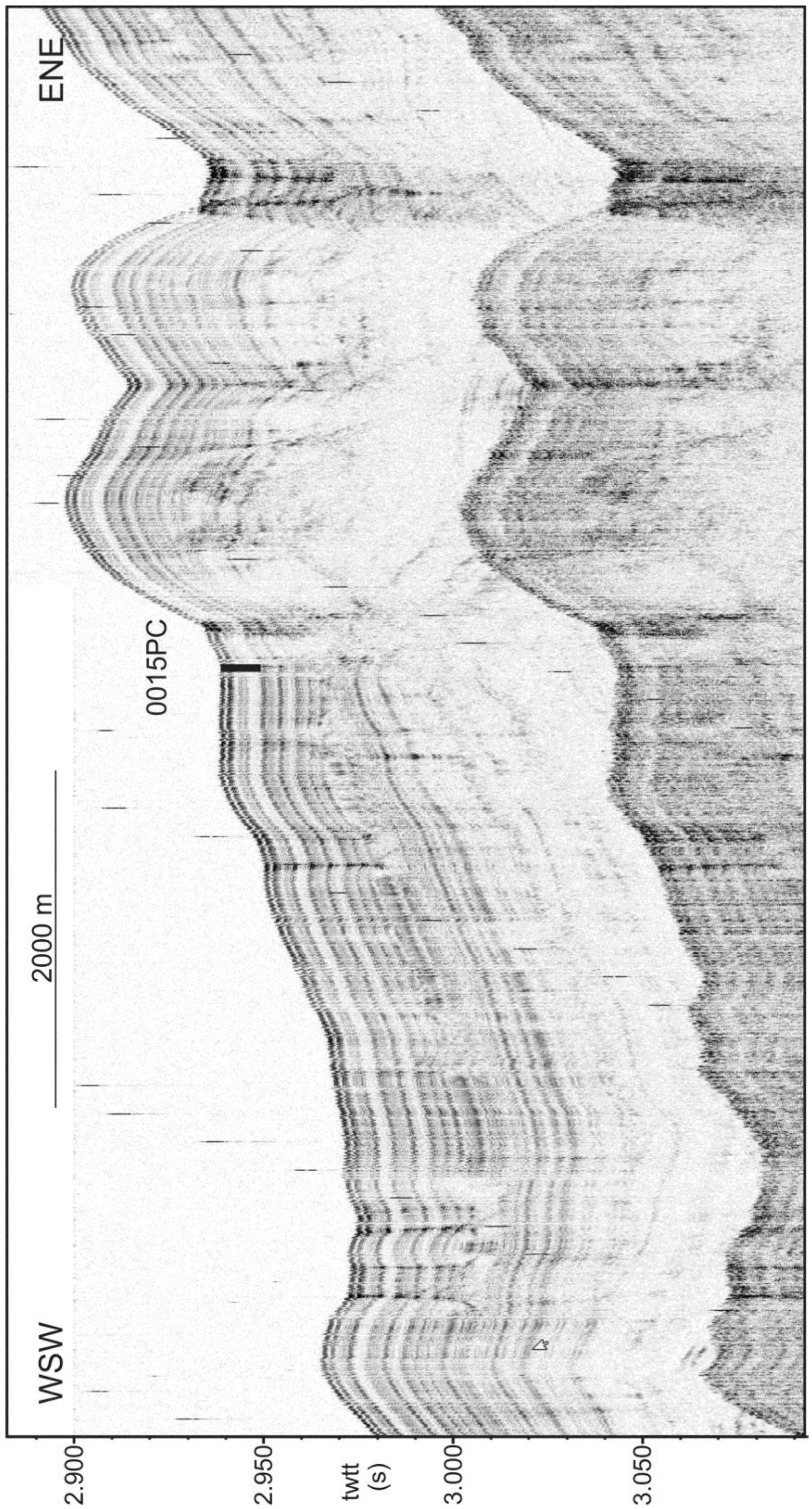

Figure 9.2.22- High resolution sub-bottom profiler data over core 0015.

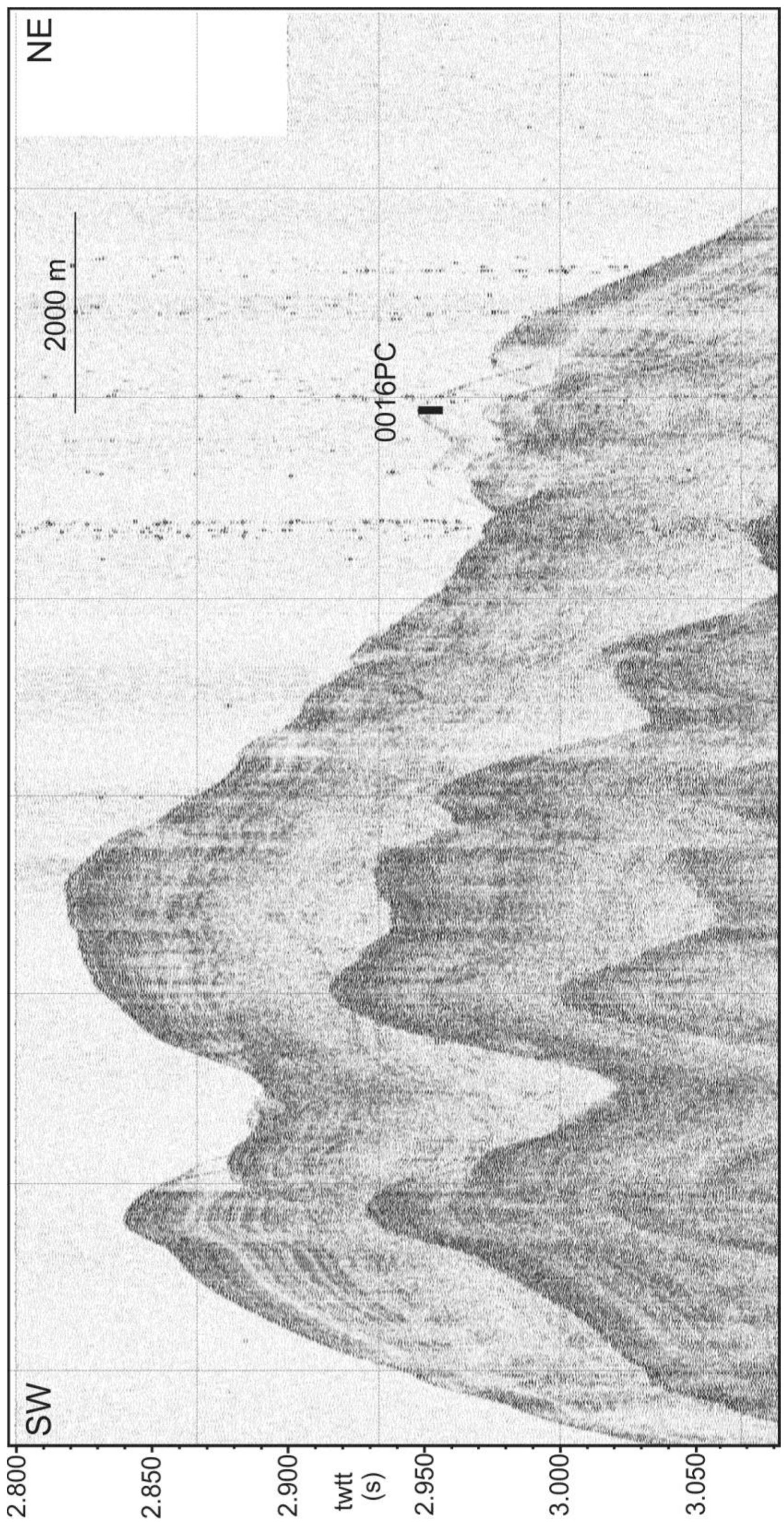

Figure 9.2.23- High resolution sub-bottom profiler data over core 0016.

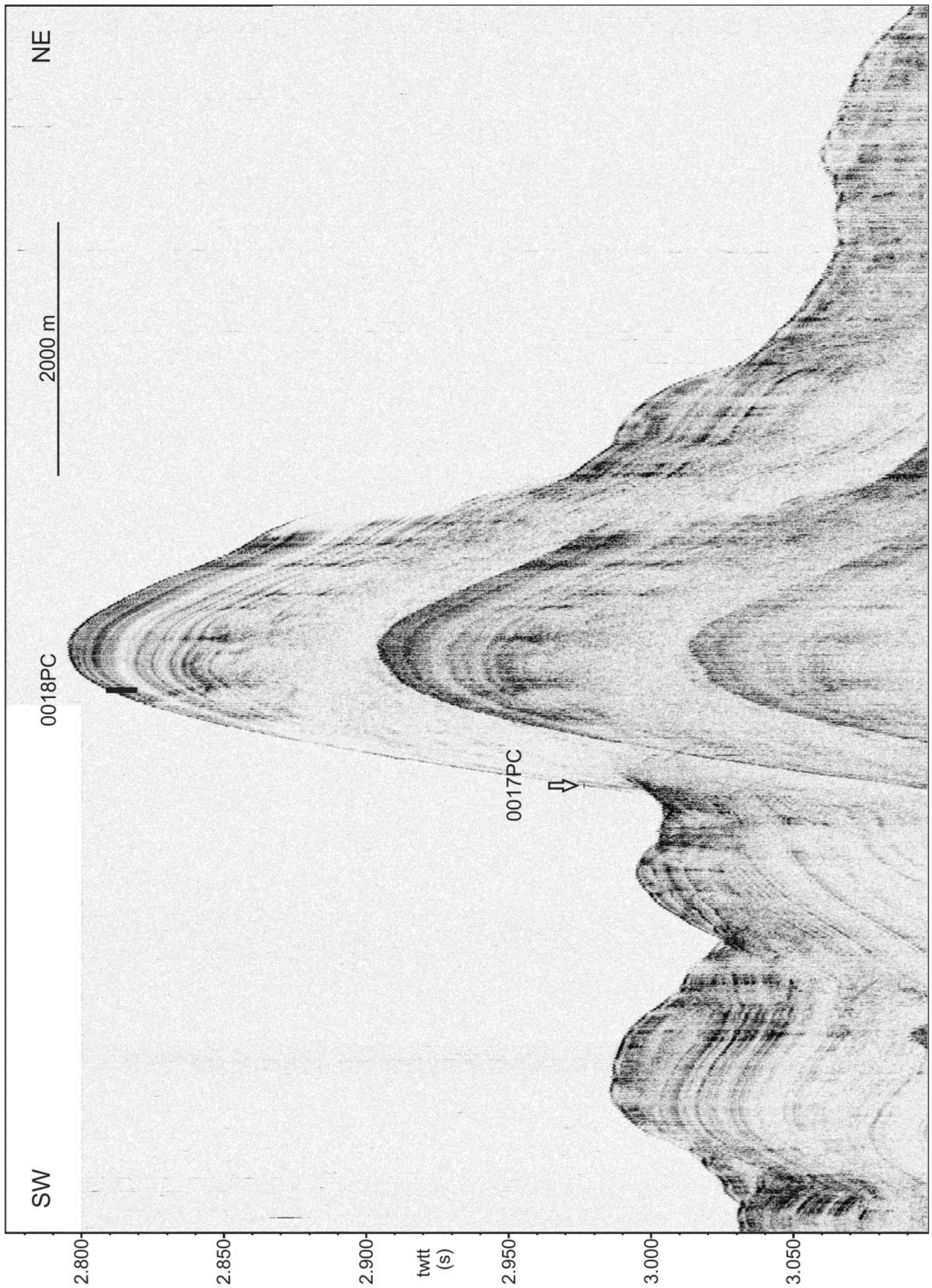

Figure 9.2.24- High resolution sub-bottom profiler data over core 0017.

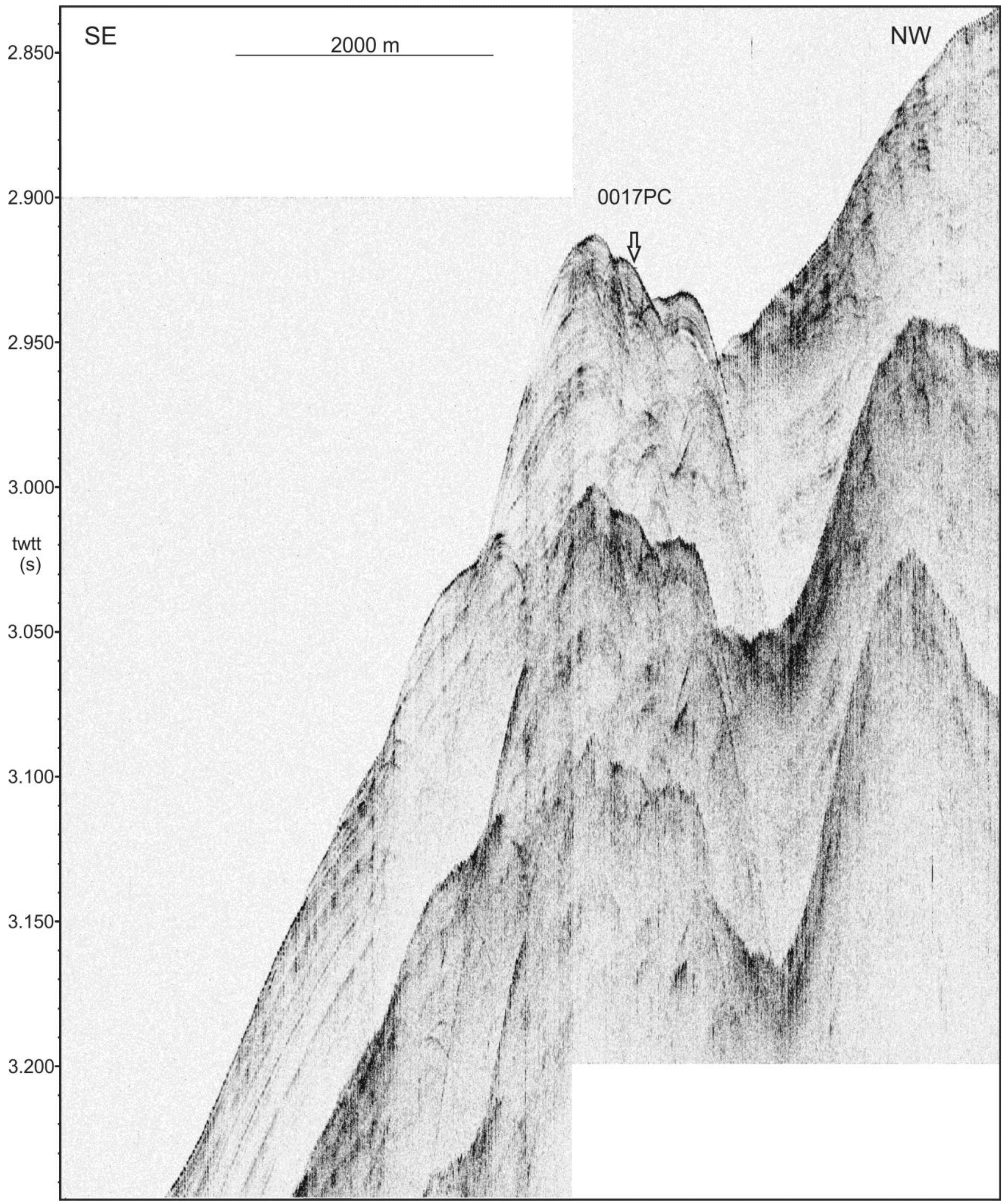

Figure 9.2.25- High resolution sub-bottom profiler data over core 0017.

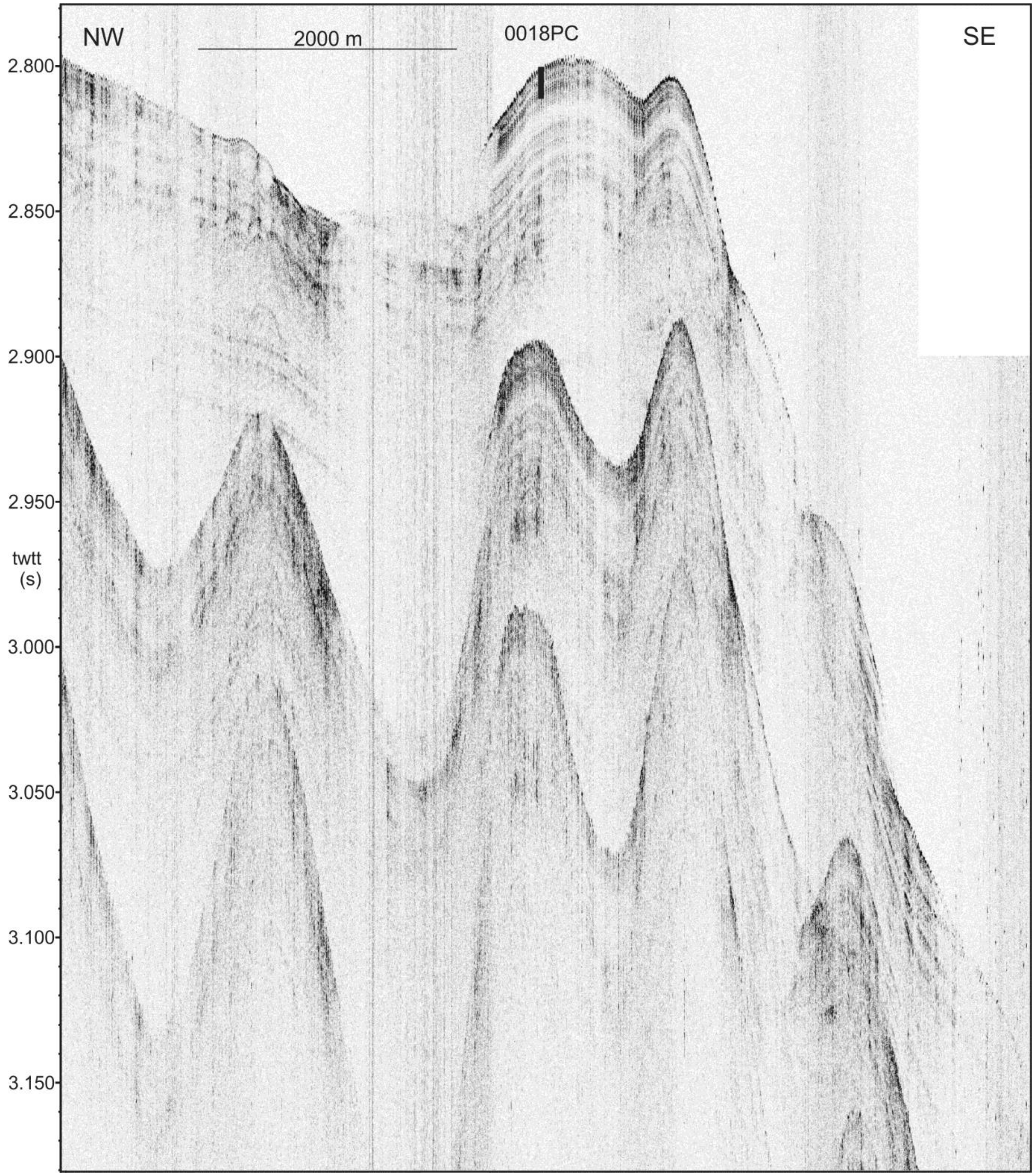

Figure 9.2.26- High resolution sub-bottom profiler data over core 0018.

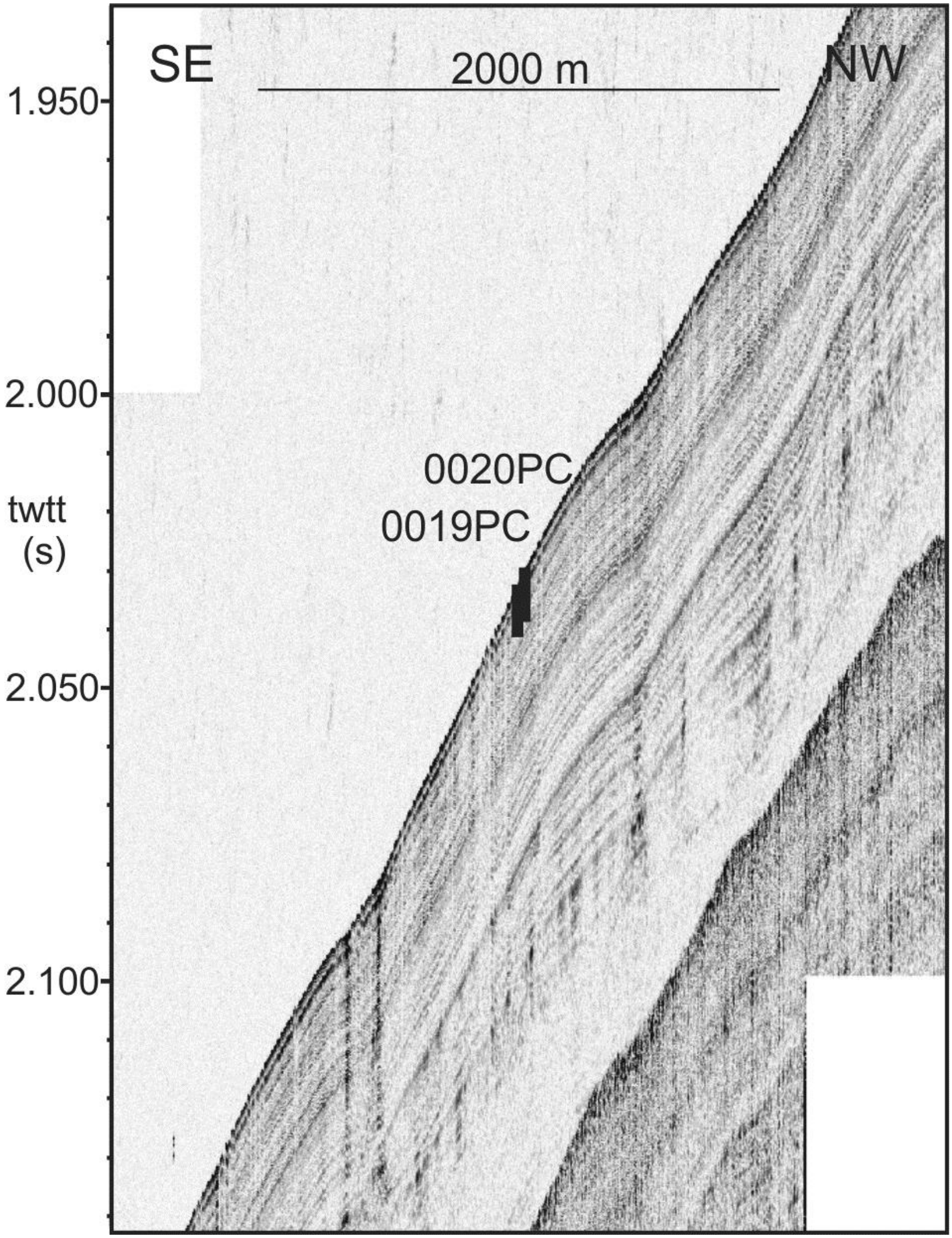

Figure 9.2.27- High resolution sub-bottom profiler data over cores 0019 and 0020.

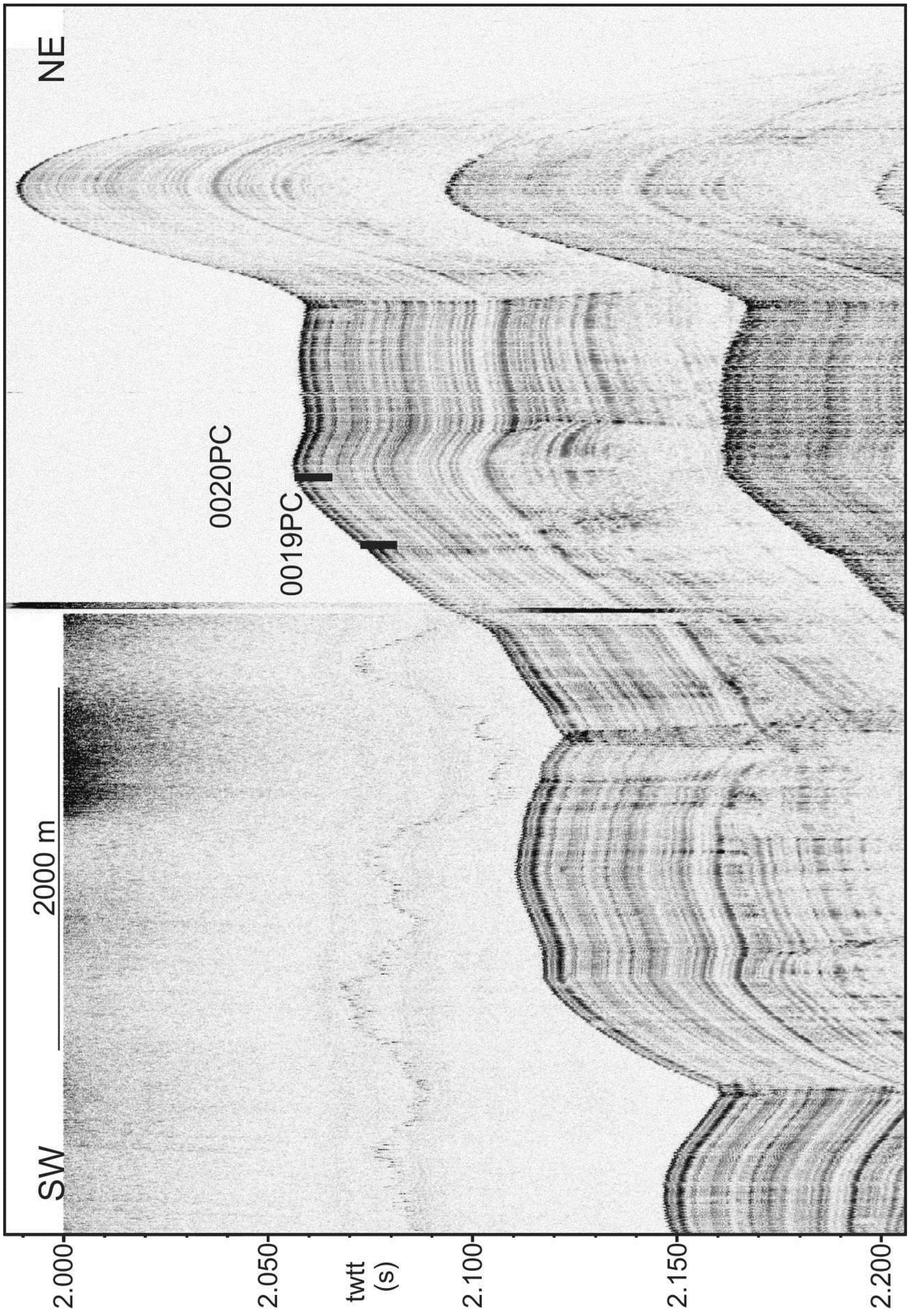

Figure 9.2.28- High resolution sub-bottom profiler data over cores 0019 and 0020.

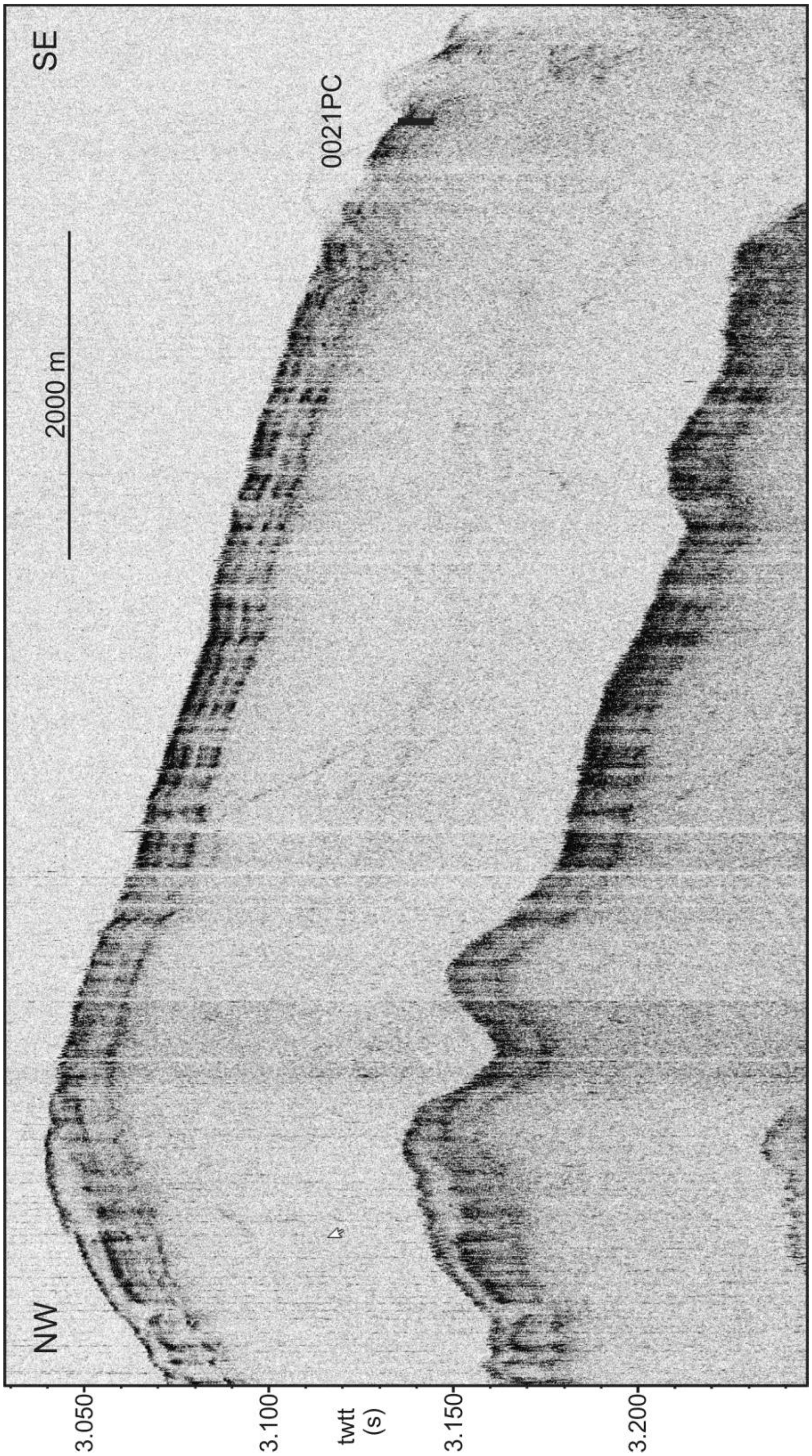

Figure 9.2.29- High resolution sub-bottom profiler data over core 0021.

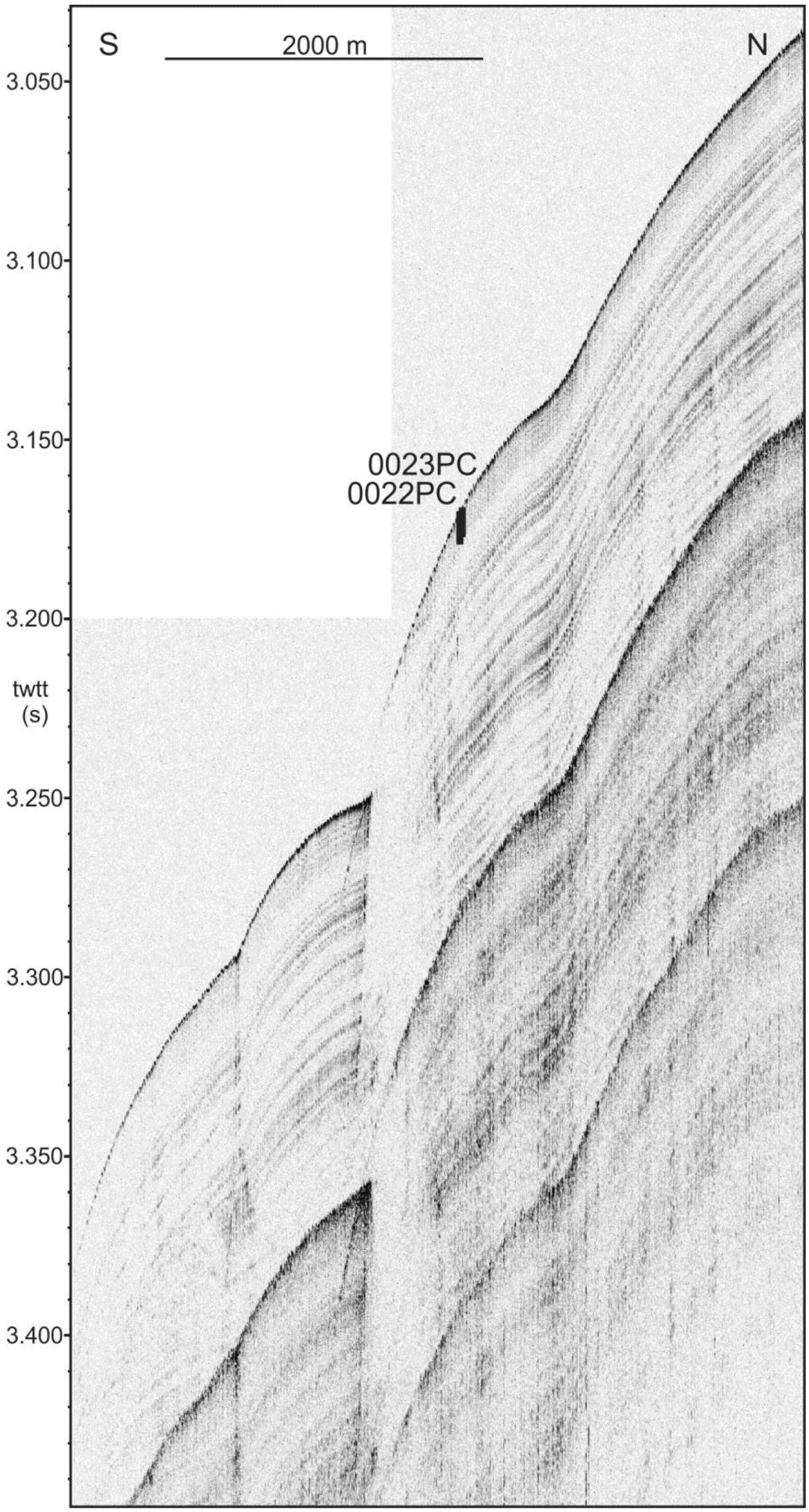

Figure 9.2.30- High resolution sub-bottom profiler data over cores 0022 and 0023.

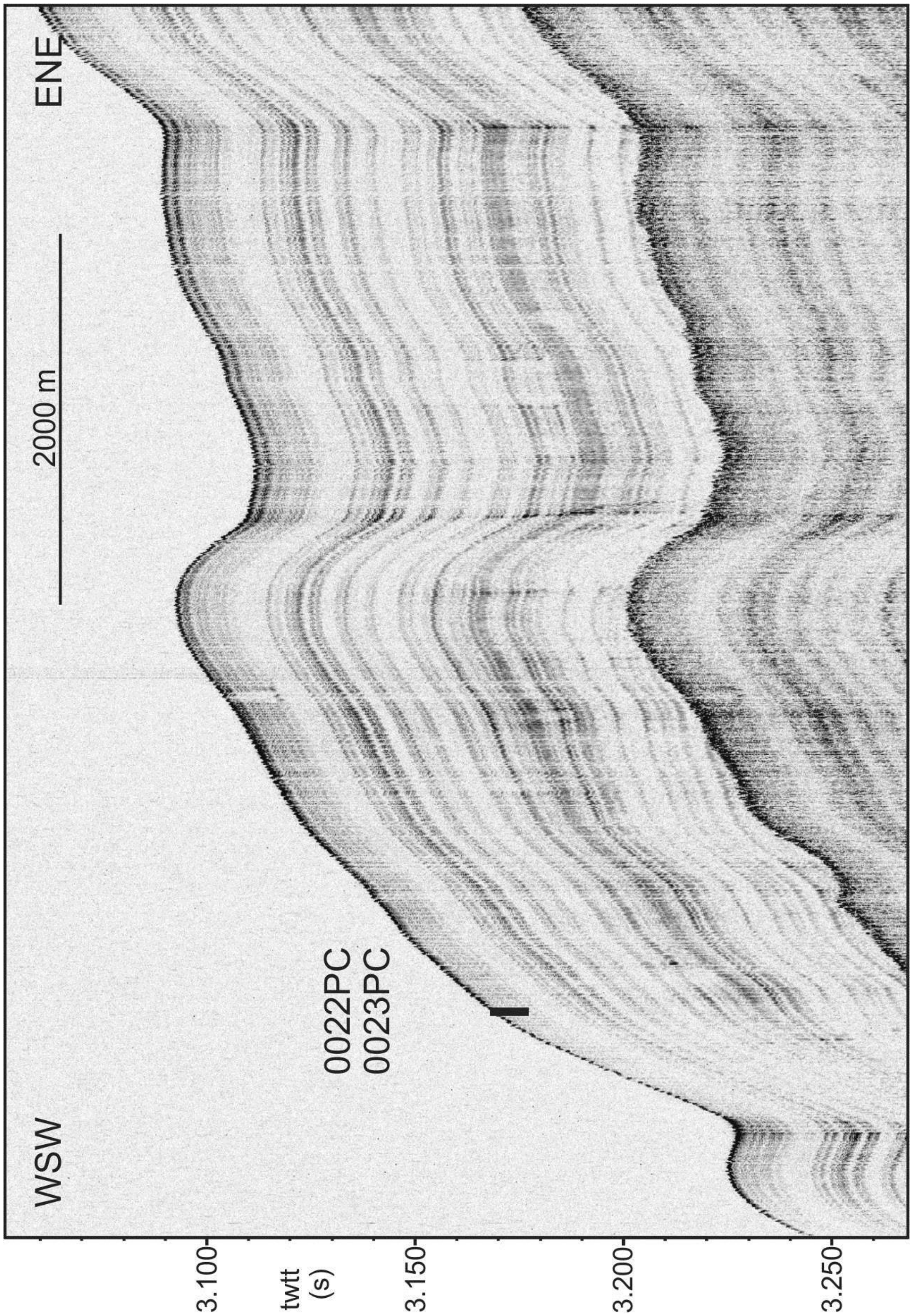

Figure 9.2.31- High resolution sub-bottom profiler data over cores 0022 and 0023.

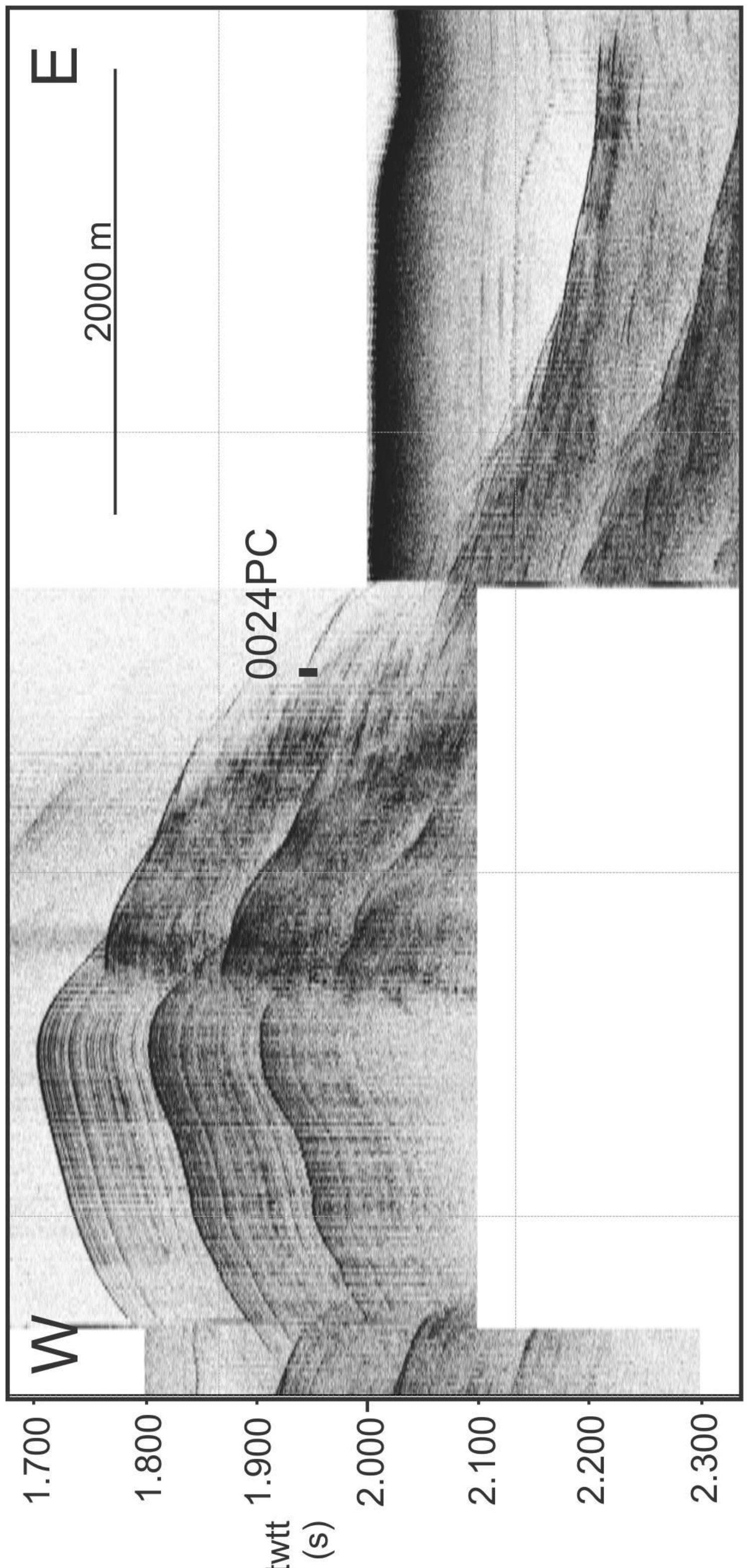

Figure 9.2.32- High resolution sub-bottom profiler data over cores 0024.

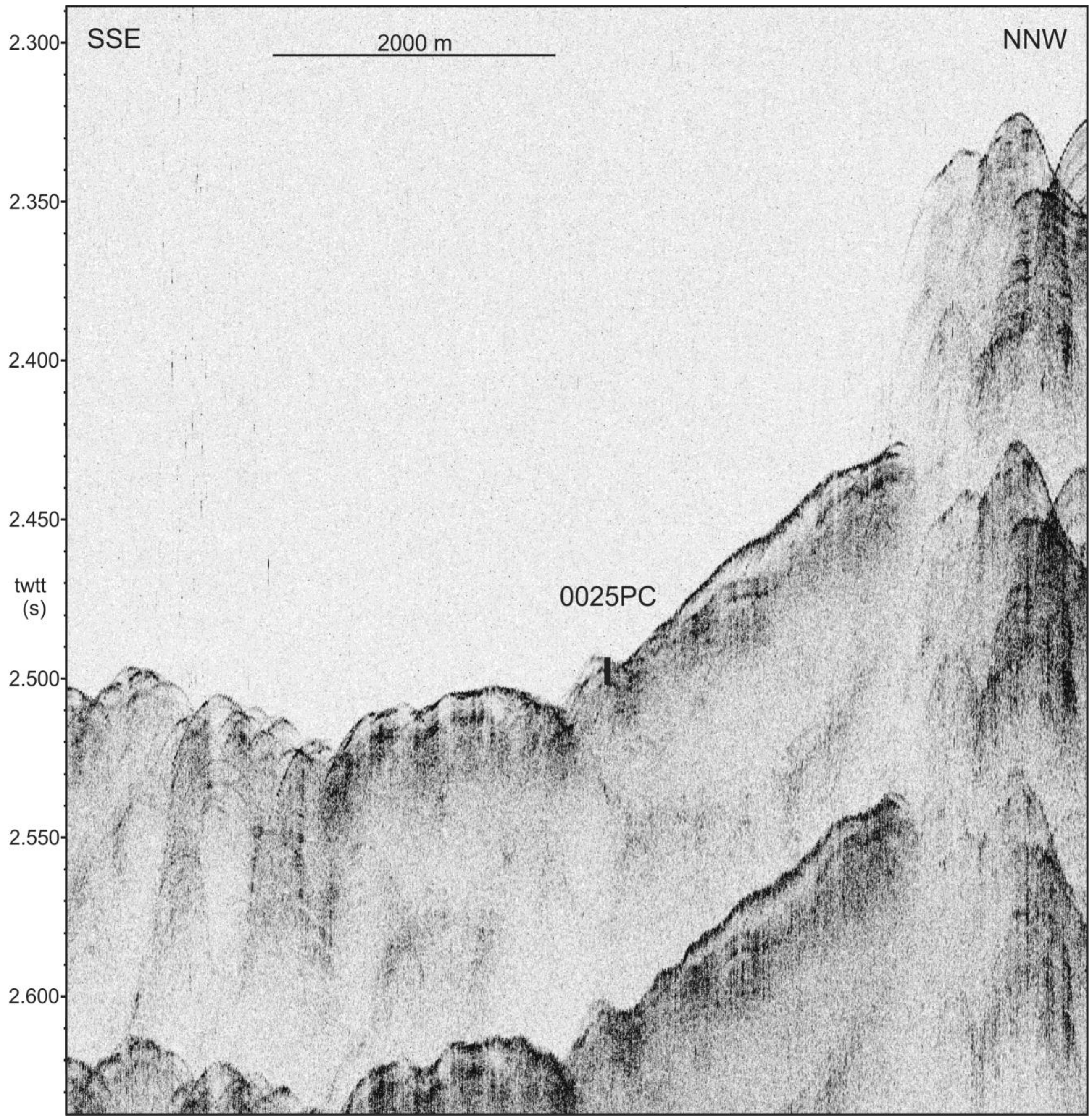

Figure 9.2.33- High resolution sub-bottom profiler data over core 0025.

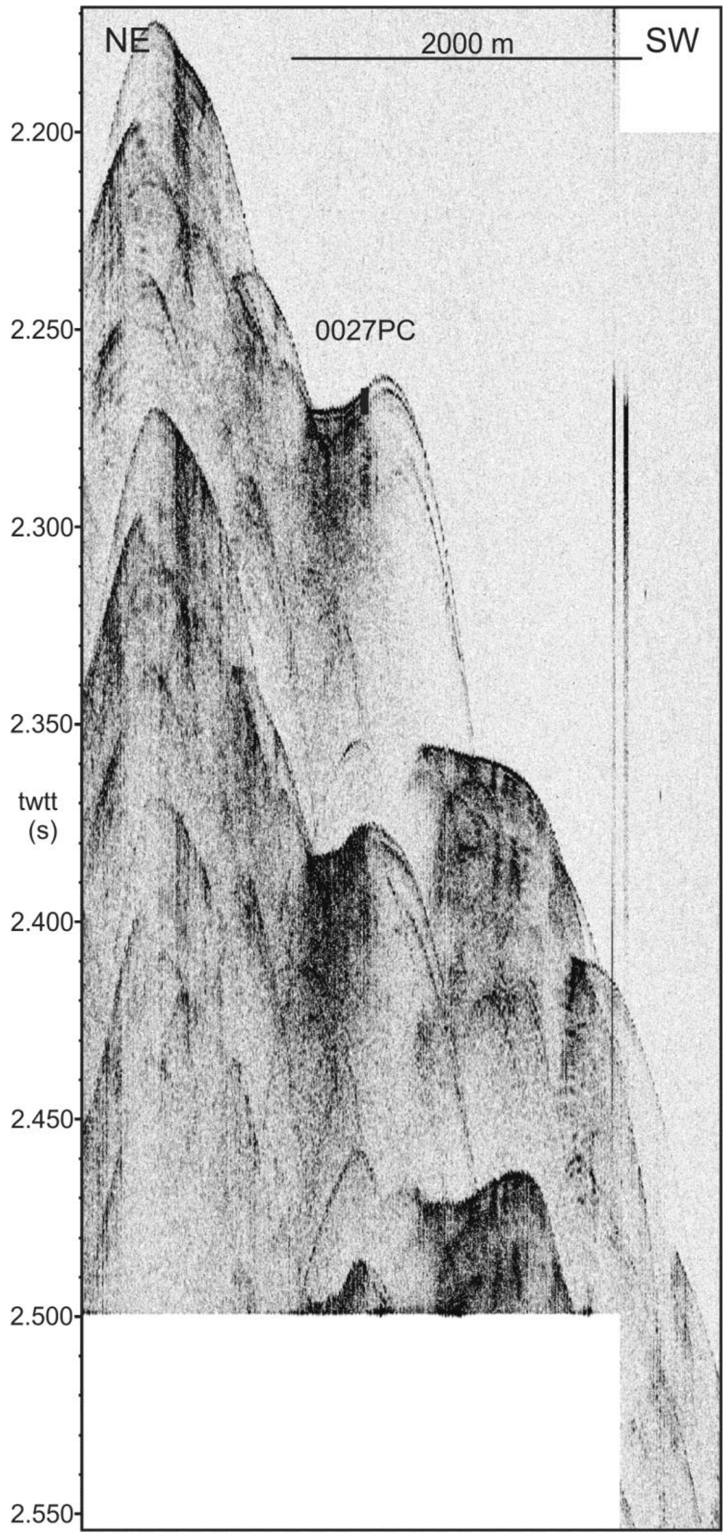

Figure 9.2.34- High resolution sub-bottom profiler data over core 0027.

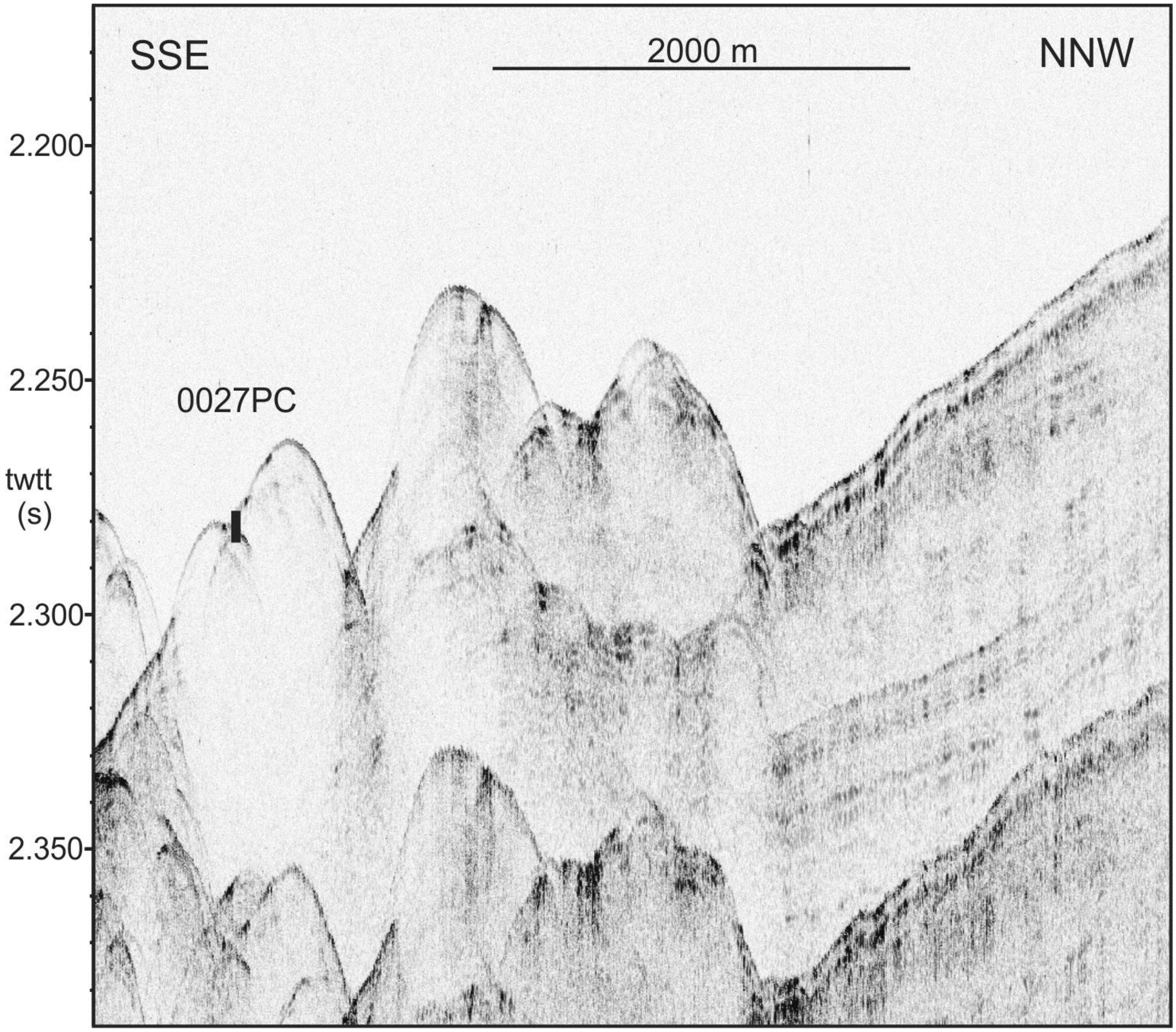

Figure 9.2.35- High resolution sub-bottom profiler data over core 0027.

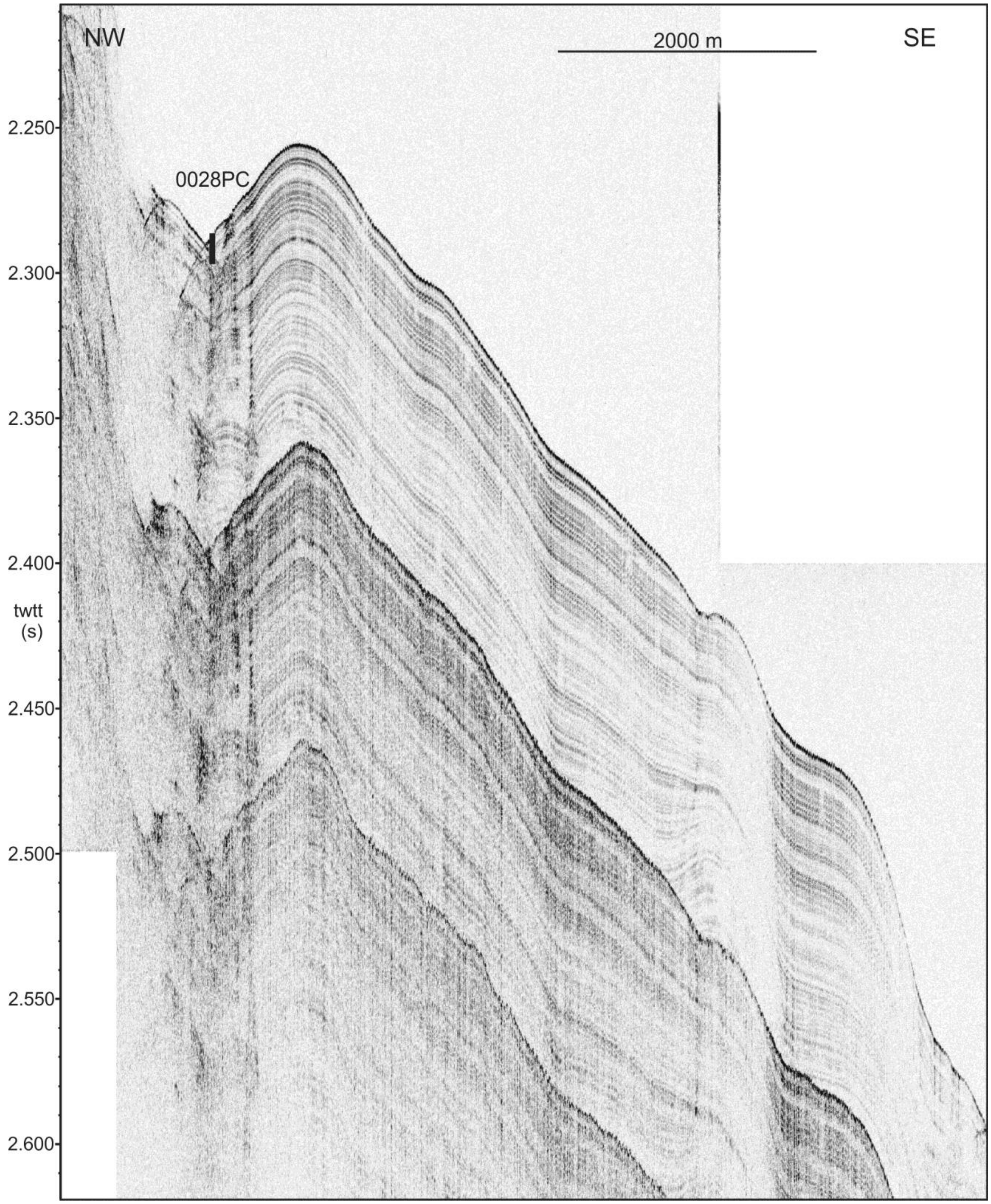

Figure 9.2.36- High resolution sub-bottom profiler data over core 0028.

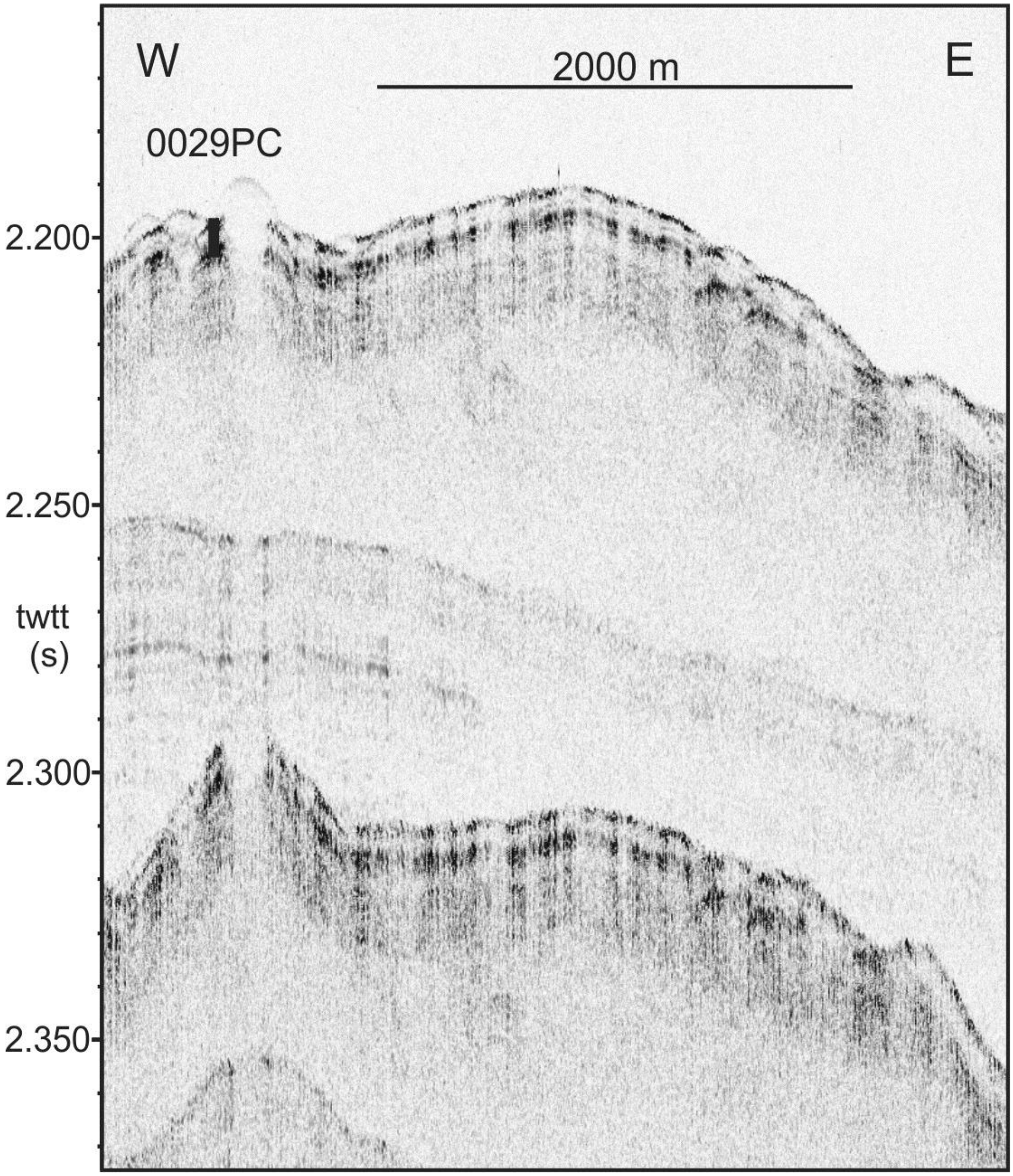

Figure 9.2.37- High resolution sub-bottom profiler data over core 0029.