International Ocean Discovery Program Expedition 374 Scientific Prospectus Addendum

Ross Sea West Antarctic Ice Sheet History

Ocean–ice sheet interactions and West Antarctic Ice Sheet vulnerability: clues from the Neogene and Quaternary record of the outer Ross Sea continental margin

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Introduction

This addendum to the International Ocean Discovery Program (IODP) *Expedition 374 Scientific Prospectus* details additional alternate sites not presented in the original prospectus. It utilizes data collected during early 2017 by the research vessel (R/V) *OGS Explora*. Additional sites based on archive data are also provided to identify sites in regions with very low sea ice risk near the beginning and end of the expedition.

Motivation for additional alternate sites

We still plan to drill the six primary sites (four continental shelf and two continental slope/rise) identified in the prospectus. Here, we identify 12 new alternate sites as risk mitigation for any sea ice scenario that may eventuate (Table **T1**; Figure **F1**). For the continental shelf sites, the biggest risk is that sites on the outer continental shelf are sea ice covered during the first few weeks of coring operations beginning in mid-January. To mitigate this, we identified two new continental shelf sites in the southern Ross Sea and three in the western Ross Sea.

Depending on sea ice conditions, we may require an icebreaker (IB) escort to leave the Ross Sea polynya. If this is required, we have to meet the RV/IB *Nathaniel B. Palmer* by ~24 February 2017, which is 5 days earlier than we would otherwise depart the Ross Sea for transit to Wellington, New Zealand. Without contingency sites outside of the Ross Sea polynya, we would lose 5 days of coring time and likely return to port early. Thus, we identified such targets to the north of the seasonal sea ice zone (proposed Sites RSCR-17A through RSCR-19A) in both the central and western Ross Sea (Figure **F1**). Site RSCR-19A was especially endorsed by the IODP Science Evaluation Panel as being a site of great interest that should be considered as a primary site, a recommendation that will be considered near the end of the expedition. We have five primary scientific objectives (McKay et al., 2017), and to achieve them, we focus on dating the seismic stratigraphic architecture, which changed in a response to shifting ice sheet dynamics and changing paleobathymetry in the Ross Sea (Figure **F2**). The main unconformities targeted by Expedition 374 sites are:

- RSU4 (16–14 Ma?): first evidence of expanded ice streams across the western to central Ross Sea.
- RSU3 (14–4 Ma?): first evidence of shelf-wide ice sheet advance from both East and West Antarctica across the Ross Sea.
- RSU2 (3.7–2 Ma?): Development of an overdeepened continental shelf and true marine-based ice sheets.
- RSU1 (~0.7 Ma?): Development of an aggradational (rather than prograding) continental shelf.

However, this expedition aims to obtain both pre-RSU4 and post-RSU4 records.

New alternate sites

Group 1

New proposed Sites RSCR-13B, RSCR-14A, and RSCR-15A are alternate sites for primary Sites RSCR-02B and RSCR-11A and alternate Site RSCR-10A, which are located on the slope/rise. They are deep-water sites directly comparable to previous targets. Relative to Site RSCR-02B, these three new sites are located on the opposite flank of the Hillary Canyon and thus are direct alternates. These new sites mitigate for local variance of sea ice in that region because there is a higher probability that ice will be more pervasive to the southeast in a bad sea ice year (near Site RSCR-02B). These new targets were surveyed in January–March 2017 and directly meet our objectives for the deeper water sites. The mound that formed on the western flank of the Hillary Canyon, where Sites RSCR-13B and RSCR-15A are located, appears to be thicker with less erosional features (i.e., more expanded/higher resolution). Alongslope/downslope currents have entrained sediment delivered along the Hillary Canyon and deposited it in this elongated sediment drift.

Group 2

Objectives for new proposed Sites RSRC-16B and RSRC-17A (deep-water sites in the northwest Ross Sea) and RSRC-18A and RSRC-19A (north of the sea ice zone) are directly comparable to previous targets in the northwest region (Sites RSCR-08A and RSCR-12B) or other deep-water sites (e.g., Site RSCR-02B). These new sites are north of the previously approved sites and are thus less likely to be influenced by sea ice, especially later in the season when icebreaker support may require us to be in this region. Sites RSCR-16B and RSCR-17A are located in the pathway of a major outflow of Antarctic Bottom Water and are likely to have more uniform sedimentation rates than Sites RSCR-08C and RSCR-12B (on the basis of Korean and Italian piston/gravity cores). The dense seismic grid in this area will allow direct correlation with Deep Sea Drilling Project (DSDP) Sites 274 and 273.

Sites RSCR-18A and RSCR-19A in the Central Ross Sea are more aligned with the eastern/central Ross Sea focus of Expedition 374. Site RSCR-18A aims to recover a pure West Antarctic Ice Sheet (WAIS) record and possibly sediment sourced from the continental shelf and carried by along-slope currents. Site RSCR-19A is located well north of the sea ice zone and provides risk mitigation if we have to leave the Ross Polynya earlier than anticipated due to icebreaker requirements. Both of these sites fulfill our objectives because they target Reflectors RSU4 and younger, which can be traced from the shelf into the abyssal plain. For Site RSCR-19A, we seek approval to a maximum penetration depth of 1265 m to core through Unconformity RSU6 (Eocene/Oligocene boundary) (see **Site-by-site review** for details).

Group 3

New proposed Sites EBOCS-11A, EBOCS-12A, and EBOCS-13A are continental shelf sites in the northwest Ross Sea. They are comparable to proposed Sites EBOCS-01D, EBOCS-02B, EBOCS-03C, and EBOCS-04B but are located in a geographically distinct region. The continental shelf sites in the western Ross Sea cover the same time intervals as our primary targets in the central embayment but may be sea ice free at times when conditions could be marginal in the central embayment. These proposed sites have more of an East Antarctic Ice Sheet (EAIS) influence but still address marine ice sheet instability and ocean–ice sheet interactions. These sites are low priority and are only included as sea ice mitigation alternates. These sites will core the key seismic reflectors (RSU4 through RSU1) and will meet the primary objectives of the expedition.

Group 4

New proposed Sites EBOCS-08A and EBOCS-09A lie to the south and are guaranteed to be sea ice free early in the season. The Coulman High sites are more northerly locations of strata previously proposed as targets by the ANDRILL program. These sites

target older Neogene strata than our primary sites, bracketed by Unconformity RSU4A (19 Ma) and the Coulman High Major Unconformity (CHMU; 26–30 Ma). These sites contain much younger strata than those proposed for the ANDRILL Coulman High project (not drilled), which targeted strata older than Unconformity RSU6 (>34 Ma).

Although we primarily target Neogene/Quaternary strata for our primary sites, an upper Oligocene/lower Neogene record still directly achieves all of our primary objectives (which are not time specific). It may enhance some of the objectives (especially Objectives 1, 2, and 4 in McKay et al., 2017), with a record passing through the Oligocene/Miocene boundary providing insights into changing ice sheet response as Earth transitioned from a warmer greenhouse world (CO_2 levels persistently exceeding 500 ppm) before transitioning to a world characterized by CO_2 levels (mostly) below 400 ppm (Figure **F2**) (Foster et al., 2017). An upper Oligocene record would also provide context regarding initial boundary conditions of bathymetry and climate prior to the Neogene cooling (Objective 5 in McKay et al., 2017).

Despite these benefits, it is not our preferred scenario to drill these sites because DSDP Site 270 and the Cape Roberts Project (CRP) have cored some of this interval already. However, these would fill in a gap of the stratigraphy between DSDP Sites 272 and 270 (Figure **F2**). This region is more likely to record volcanic ashes (for age control) than Site 270 because it is in the vicinity of the McMurdo Volcanic Region. The CRP cores also cover some of this interval, but they are influenced by erosion through expansion of local EAIS outlet glaciers (Naish et al., 2001). Drilling at proposed Sites EBOCS-08A and EBOCS-09A will be in a deeper water paleoenvironment and thus not as directly influenced by local ice cap advance as the CRP sites; therefore, they are anticipated to be more continuous (pre-RSU4 glaciomarine strata result from local ice cap advances on bathymetric highs). These sites thus provide context for identifying the thresholds for marine based ice sheet expansions versus local outlet glacier/ice cap expansion.

We also aim to obtain pre-RSU4 targets at primary Site EBOCS-01D, so these new alternate sites are aligned with that objective. Most importantly, these sites open up very early in the season and are a guaranteed target for the first couple of weeks in a worst case sea ice year.

Site-by-site review

Site RSCR-13B

Proposed Site RSCR-13B is in a very similar depositional setting to Sites RSCR-02B and RSCR-10A (i.e., a drift on the adjacent flank of the Hillary Canyon). It seeks to recover a semicontinuous to continuous record back to Unconformity RSU3 (mid-Miocene?), which occurs at ~440 meters below seafloor (mbsf). It is an alternate for primary Site RSCR-02B. We will also seek to recover a pre-RSU3 record at this site (to 1000 mbsf).

Site RSCR-14A

Proposed Site RSCR-14A is in a very similar depositional setting to Site RSCR-11A (i.e., a drift on the upper continental slope). It seeks to recover a semicontinuous to continuous record back to, and through, Unconformity RSU4 (mid-Miocene), which occurs at ~380 mbsf. It is an alternate for primary Site RSCR-11A, and we plan to drill to basement.

Site RSCR-15A

Proposed Site RSCR-15A is in a very similar depositional setting to Sites RSCR-02B and RSCR-10A (i.e., a drift on the adjacent flank of the Hillary Canyon). It seeks to recover a semicontinuous to continuous record back to Unconformity RSU3 (mid-Miocene?), which occurs at ~690 mbsf. It is an alternate for primary Site RSCR-02B. We will also seek to recover a pre-RSU3 record at this site (to 1000 msbf).

Site RSCR-16B (Cape Adare)

Proposed Site RSCR-16B is a drift located in the Cape Adare region. It seeks to recover a semicontinuous to continuous record between Unconformities RSU2 (Pliocene) and RSU4 (mid-Miocene?), which occurs at ~900 mbsf, but will also contain a post-RSU2 record in the upper 120 mbsf. It is an alternate for primary Site RSCR-02B.

Site RSCR-17A (Cape Adare)

Proposed Site RSCR-17A is a drift located in the Cape Adare region. It seeks to recover a thick semicontinuous to continuous record between Unconformities RSU2 (Pliocene) and RSU4 (mid-Miocene?), which occur at ~65 and 320 mbsf, respectively. It will also contain a post-RSU2 record in the upper 65 mbsf. It is an alternate for primary Site RSCR-02B. We plan to drill to 500 mbsf.

Site RSCR-18A

Proposed Site RSCR-18A is a drift located in the eastern Ross Sea to the east of our other drill sites. It seeks to recover a thick semicontinuous to continuous post-RSU3 record (mid-Miocene to early Pliocene?), which occurs at ~600 mbsf, but will also contain a post-RSU3 record in the upper 600 mbsf. It is an alternate for primary Site RSCR-02B. We aim to drill to 900 mbsf.

Site RSCR-19A

Proposed Site RSCR-19A is a drift located in the outer eastern Ross Sea to the north of our other drill sites and well north of seasonal sea ice. It seeks to recover a thick continuous Eocene/Oligocene to present record and is an alternate for primary Site RSCR-02B. The shallow seismic sequence can be traced indirectly onto the eastern Ross Sea continental shelf (Lindeque et al., 2016) and thus still directly meets our objectives for the deeper water sites.

Because this site (if drilled) is likely to be the last one occupied, especially if we have to leave early for icebreaker reasons, we request to drill into lower Paleogene strata (if time permits) after primary objectives to penetrate Unconformity RSU4 (at ~0.5 s two-way traveltime [TWT]) have been achieved. Parasound profiles indicate very well stratified beds in the upper ~100 mbsf of this site, which is likely to be Pleistocene in age (e.g., post-RSU2).

This site also holds particular promise because the Ross Sea seismic stratigraphy can be connected to the Amundsen Sea and thus provides an opportunity to integrate results between Expeditions 374 and 379 (Amundsen Sea WAIS history) (Lindeque et al., 2016).

Site EBOCS-11A

Proposed Site EBOCS-11A is located on the continental shelf of the western Ross Sea, an area where sea ice is usually less than in the outer eastern Ross Sea. It is an alternate for primary Site EBOCS-

02B, targets the same age strata (Unconformities RSU4 through RSU2), and will achieve the same objectives (but with a marine-based EAIS influence). It is an alternate only for a bad sea ice year. Unconformity RSU4 is located at ~375 mbsf, and Unconformity RSU2 is at ~225 mbsf. We aim to drill to a total depth of 520 mbsf (where the seafloor multiple is present).

Site EBOCS-12A

Proposed Site EBOCS-12A is located in a similar region to Site EBOCS-11A. It is an alternate for primary Sites EBOCS-03C and EBOCS-04B, targets the same age strata (Unconformity RSU4 [mid-Miocene] to late Pleistocene), and will achieve the same objectives (but with a marine-based EAIS influence). It is an alternate only for a bad sea ice year. Unconformity RSU4 is located at ~1010 mbsf, and Unconformity RSU2 is at ~500 mbsf.

Site EBOCS-13A

Proposed Site EBOCS-13A is located in a similar region to Site EBOCS-11A. It is an alternate for primary Sites EBOCS-03C and EBOCS-04B, targets the same age strata (Unconformity RSU4 [mid-Miocene] to late Pleistocene), and will achieve the same objectives (but with a marine-based EAIS influence). It is an alternate only for a bad sea ice year. Unconformity RSU4 is located at ~1100 mbsf, and Unconformity RSU2 is at ~500 mbsf. We aim to drill to 1000 mbsf.

Sites EBOCS-08A and EBOCS-09A

Proposed Sites EBOCS-08A and EBOCS-09A are located on Coulman High and target an older stratigraphic sequence than primary Site EBOCS-01D. These sites penetrate a series of prograding glaciomarine strata separated by glacial Unconformities RSU4A (19 Ma) and CHMU (30 Ma?). As noted above, these are older strata than those at our primary sites, but they are still glaciomarine deposits that will achieve objectives related to our primary sites but for slightly older time periods. We include these sites because they are located in the first region of the Ross Sea polynya to become open water and thus mitigate early season sea ice risk (they will only be drilled in poor sea ice conditions).

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Table T1. Summary of Expedition 374 primary and alternate sites. EPSP = Environmental Protection and Safety Panel.

Proposed site	Primary seismic line	Latitude	Longitude	Water depth (m)	Proposed penetration (mbsf)	EPSP approved penetration (mbsf)	Coring plan	Logging plan	Anticipated age at proposed penetration depth (Ma)
Primary sites									
EBOCS-03C	SP300 on line IO6290-Y2A	76.55380°S	174.75794°W	558	545	545	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	mid-Miocene
EBOCS-01D	SP690 on line PD90-36	75.68392°S	179.67179°W	566	950	950	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	mid-Miocene
EBOCS-04B	SP5162 on line PD90-30	76.17651°S	172.88398°W	480	520	520	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	Pliocene
RSCR-02B	SP4050 on line ATC82B-208	74.50592°S	172.85452°W	2550	1000	1000	Hole A: APC Hole B: APC/XCB/RCB	Hole B: TC, FMS-sonic, VSI	mid-Miocene
RSCR-11A	SP1800 on line IT91A-88B	71.84603°S	175.67904°W	1534	500	500	Hole A: APC Hole B: APC/XCB/RCB	Hole B: TC, FMS-sonic, VSI	Pliocene
EBOCS-02B	SP3160 on line PD90-35	76.08827°S	178.09119°W	658	500	500	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	mid-Miocene
Alternate sites									
EBOCS-05A	SP1838 on line PD90-36	75.54986°S	179.20599°E	525	700	700	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	mid-Miocene
EBOCS-06A	SP1315 on line IO6290-Y7	75.91448°S	175.34958°W	515	700	700	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	mid-Miocene
EBOCS-07C	SP3500 on line IO6290-Y7B	76.19502°S	173.70576°W	540	750	750	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	Pliocene
EBOCS-08A	SP437 on line NBP0301-34B	77.242528°S	172.36400°E	672	1000	1000	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	Oligocene
EBOCS-09A	SP600 on line NBP0301-06A	77.247108°S	171.622215°E	764	1300	1300	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	Oligocene
EBOCS-11A	SP3327 on line BGR80-001	73.49652175°S	174.6760289°E	380	520	520	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	mid-Miocene
EBOCS-12A	SP1128 on line BGR80-001	72.50159422°S	174.6883478°E	489	1050	1050	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	late Miocene
EBOCS-13A	SP2645 on line IT91A-88	72.5046448°S	173.6860300°E	460	1150	1150	Hole A: RCB	Hole A: TC, FMS-sonic, VSI	late Miocene
RSCR-01B	SP10430 on line IT88-01C	75.24660°S	175.00582°W	1400	1000	1000	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-03A	SP1660 on line IT94A-127	75.00100°S	173.92012°W	1824	800	800	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-08C	SP10095 on line BGR80-008A	73.36928°S	178.91774°E	700	1000	1000	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-10A	SP5000 on line TAN0602-08	74.21739°S	173.63372°W	2390	1000	1000	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-12B	SP6500 on line IT91A-88	71.85123°S	178.16371°E	1952	620	650	Hole A: APC Hole B: APC/XCB	Hole B: TC, FMS-sonic, VSI	late Miocene?
RSCR-13B	SP82597 on line IT17RS-318	73.9175423°S	175.349974°W	2390	1000	1000	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-14A	SP48387 on line IT17RS-301	74.1502999°S	176.795129°W	810	950	950	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-15A	SP55748 on line IT17RS-303B	73.920300°S	174.598800°W	2475	1000	1000	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-16B	CDP5750 on line NBP9702-06A	70.59171889°S	172.91573501°E	2340	950	950	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	mid-Miocene
RSCR-17A	CDP11630 on line NBP9702-06A	70.799113°S	174.70677°E	2350	500	500	Hole A: APC Hole B: APC/XCB	Hole B: TC, FMS-sonic, VSI	mid-Miocene
RSCR-18A	SP9000 on line TAN0602-04P4	73.910571°S	162.456325°W	3650	650	650	Hole A: APC Hole B: APC/XCB	Hole B: TC, FMS-sonic, VSI	late Miocene
RSCR-19A	CDP6950 on line AWI-20100107	70.327650°S	164.70000°W	4250	920	Requesting to 1265	Hole A: APC Hole B: APC/XCB Hole C: RCB	Hole C: TC, FMS-sonic, VSI	Eocene

Figure F1. Location of primary and alternate Expedition 374 sites relative to average (1979–2007) sea ice concentrations in February. Note the addition of new alternate sites in four distinct regions to account for early and late season sea ice risk.

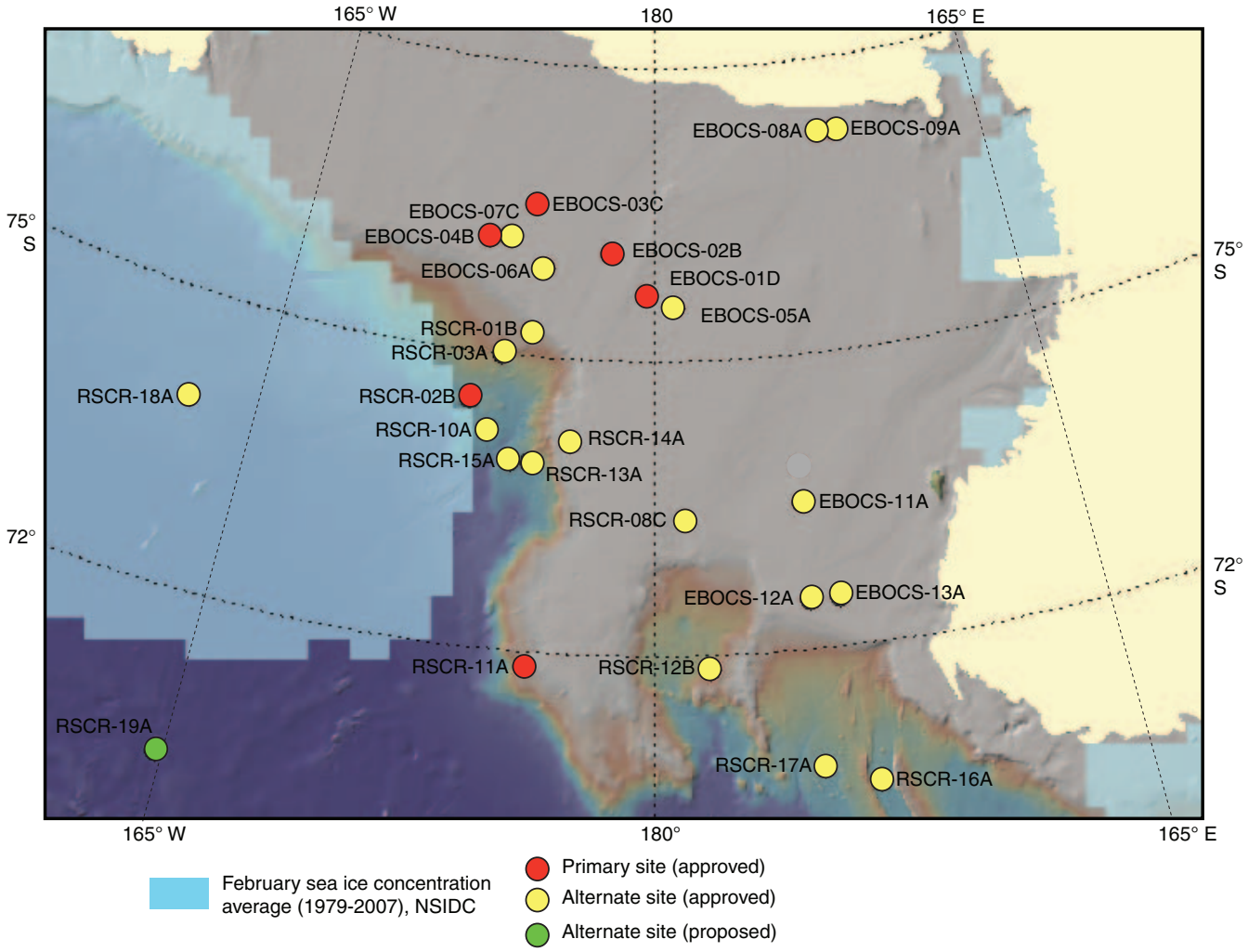
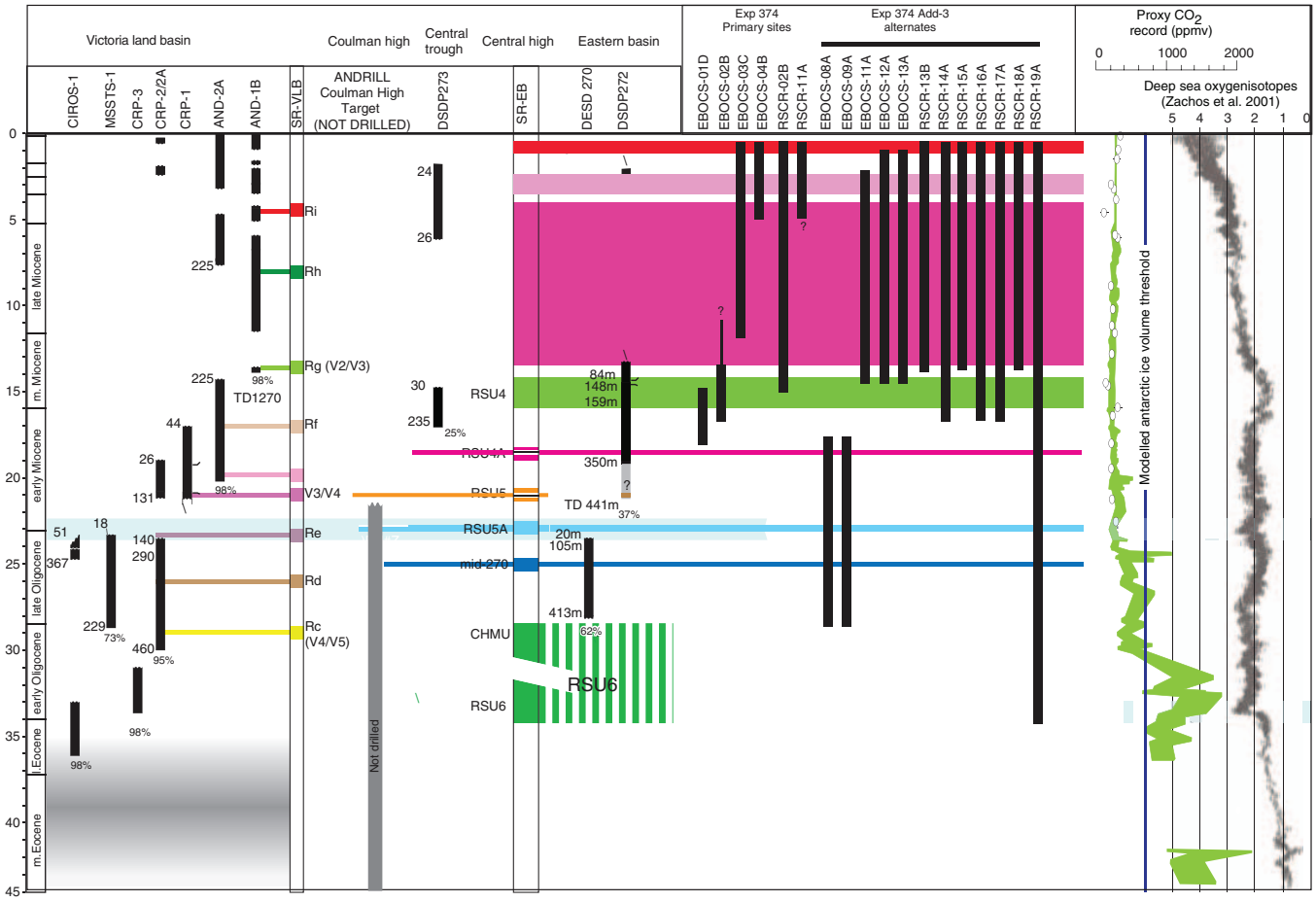


Figure F2. Seismic stratigraphy of the Ross Sea as constrained by previous drilling, along with the target stratigraphic intervals for Expedition 374 to reduce the uncertainties associated with Unconformities RSU4 through RSU2. Temporal distributions of the new proposed alternate sites are also shown. Targets for all new sites overlap with those of sites included in the *Scientific Prospectus*, with the exception of Sites EBOCS-08A, EBOCS-09A, and RSCR-19A. Sites EBOCS-08A and EBOCS-09A have thick intervals of strata between Unconformities RSU4A and RSU5A, which are poorly constrained and cover the Oligocene/Miocene boundary, a key period of cooling and declining atmospheric CO_2. Note that all EBOCS sites will core discontinuous stratigraphies. SR-VL = seismic reflectors Victoria Land, SR-EB = seismic reflectors Eastern Basin.



Site summaries

Site EBOCS-08A

Priority:	Alternate
Position:	77.242528°S, 172.36400°E
Water depth (m):	672
Target drilling depth (mbsf):	1000
Approved maximum penetration (mbsf):	1000
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF1**) Deep-penetration seismic reflection: • Primary line: SP437 on line NBP0301-34B (Figure **AF2**) • Crossing line: SP4886 on line NBP0301-09A (Figure **AF3**)
Objective(s):	• Constrain age of Unconformities RSU4A, RSU5A, mid-270, and CHMU • Recover sediments spanning the Oligocene/Miocene boundary to provide insight into changing ice sheet response as the Earth transitioned from the high-CO_2 greenhouse world to lower CO_2 (<400 ppm) icehouse world • Obtain an Oligocene record to provide initial boundary conditions (e.g., bathymetry and climate) prior to Neogene cooling
Drilling program:	Hole A: RCB to 1000 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole A: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Glaciomarine and subglacial diamicts and mudstones, with possible open marine mudstone and biogenic ooze

Site EBOCS-09A

Priority:	Alternate
Position:	77.247108°S, 171.622215°E
Water depth (m):	764
Target drilling depth (mbsf):	1300
Approved maximum penetration (mbsf):	1300
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF1**) Deep-penetration seismic reflection: • Primary line: SP600 on line NBP0301-06A (Figure **AF4**)
Objective(s):	• Constrain age of Unconformities RSU4A, RSU5A, mid-270, and CHMU • Recover sediments spanning the Oligocene/Miocene boundary to provide insight into changing ice sheet response as the Earth transitioned from the high-CO_2 greenhouse world to lower CO_2 (<400 ppm) icehouse world • Obtain an Oligocene record to provide initial boundary conditions (e.g., bathymetry and climate) prior to Neogene cooling
Drilling program:	Hole A: RCB to 1300 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole A: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Glaciomarine and subglacial diamicts and mudstones, with possible open marine mudstone and biogenic ooze

Site EBOCS-11A

Priority:	Alternate (for EBOCS-02B, but with marine-based East Antarctic Ice Sheet [EAIS] influence)
Position:	73.49652175°S, 174.6760289°E
Water depth (m):	380
Target drilling depth (mbsf):	520
Approved maximum penetration (mbsf):	520
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF5**) Deep-penetration seismic reflection: • Primary line: SP3327 on line BGR80-001 (Figure **AF6)** • Crossing line: SP2365 on line TH91-25SMG (Figure **AF7**)
Objective(s):	• Establish timing of first marine-based ice streams into Ross Sea (RSU4) • Determine if glacial advance associated with RSU4 was from localized ice caps or shelf-wide ice sheet advance • Recover a mid- to upper Miocene climate, oceanic, and ice sheet record from glaciomarine and subglacial till above RSU4
Drilling program:	Hole A: RCB to 520 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole A: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Glaciomarine and subglacial diamicts and mudstones, with possible open marine mudstone and biogenic ooze

Site EBOCS-12A

Priority:	Alternate (for EBOCS-02B, but with marine-based EAIS influence)
Position:	72.50159422°S, 174.6883478°E
Water depth (m):	489
Target drilling depth (mbsf):	1050
Approved maximum penetration (mbsf):	1050
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF8**) Deep-penetration seismic reflection: • Primary line: SP1128 on line BGR80-001 (Figure **AF9**) • Crossing line: SP2709 on line TH91-26SMG (Figure **AF10**)
Objective(s):	• Establish timing of first marine-based ice streams into Ross Sea (RSU4) • Determine if glacial advance associated with RSU4 was from localized ice caps or shelf-wide ice sheet advance • Recover a discontinuous upper Miocene to Pleistocene climate, oceanic, and ice sheet record from glaciomarine and subglacial till above RSU4 on the outer shelf.
Drilling program:	Hole A: RCB to 1050 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole A: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Glaciomarine and subglacial diamicts and mudstones, with possible open marine mudstone and biogenic ooze

Site EBOCS-13

Priority:	Alternate (for EBOCS-02B, but with marine-based EAIS influence)
Position:	72.5046448°S, 173.6860300°E
Water depth (m):	460
Target drilling depth (mbsf):	1150
Approved maximum penetration (mbsf):	1150
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF8**) Deep-penetration seismic reflection: • Primary line: SP2645 on line IT91A-88 (Figure **AF11**) • Crossing line: SP2003 on line TH91-26SMG (Figure AF46)
Objective(s):	• Establish timing of first marine-based ice streams into Ross Sea (RSU4) • Determine if glacial advance associated with RSU4 was from localized ice caps or shelf-wide ice sheet advance • Recover a discontinuous upper Miocene to Pleistocene climate, oceanic, and ice sheet record from glaciomarine and subglacial till above RSU4 on the outer shelf.
Drilling program:	Hole A: RCB to 1150 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole A: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Glaciomarine and subglacial diamicts and mudstones, with possible open marine mudstone and biogenic ooze

Site RSCR-13B

Priority:	Alternate (for RSCR-02B)
Position:	73.9175423°S, 175.349974°W
Water depth (m):	2390
Target drilling depth (mbsf):	1000
Approved maximum penetration (mbsf):	1000
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF13**) Deep-penetration seismic reflection: • Primary line: SP82597 on line IT17RS-318 (Figure AF48) • Crossing line: SP52382 on line IT17RS-302 (Figure **AF15**)
Objective(s):	• Obtain a near-continuous post-RSU3 (mid-Miocene to Pleistocene?) and pre-RSU3 (mid-Miocene to Pliocene) sediment sequence to provide a high-resolution chronology and an ice-distal record of glacial–interglacial cycles • Recover a high-resolution record for correlation to inner and outer shelf records and mid- to high latitude deep-sea records of glacial and environmental change • Reconstruct Antarctic Slope Current vigor and Ross Sea Bottom Water production
Drilling program:	Hole A: APC to 250 mbsf with nonmagnetic core barrels, orientation (Icefield tool), and APCT-3 Hole B: APC/XCB to 350 mbsf with nonmagnetic core barrels and orientation (APC only) Hole C: RCB to 1000 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole C: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Turbiditic/contouritic mud alternating with hemipelagic biogenic mud

Site RSCR-14A

Priority:	Alternate (for RSCR-02B)
Position:	74.1502999°S, 176.795129°W
Water depth (m):	810
Target drilling depth (mbsf):	950
Approved maximum penetration (mbsf):	950
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF13**) Deep-penetration seismic reflection: • Primary line: SP48387 on line IT17RS-301 (Figure **AF16**) • Crossing line: SP4218 on line IT94R-127A (Figure **AF17**)
Objective(s):	• Obtain a near-continuous post-RSU3 (mid-Miocene to Pleistocene?) and pre-RSU3 (mid-Miocene to Pliocene) sediment sequence to provide a high-resolution chronology and an ice-distal record of glacial/interglacial cycles • Recover a high-resolution record for correlation to inner and outer shelf records and mid- to high latitude deep-sea records of glacial and environmental change • Reconstruct Antarctic Slope Current vigor and Ross Sea Bottom Water production
Drilling program:	Hole A: APC to 250 mbsf with nonmagnetic core barrels, orientation (Icefield tool), and APCT-3 Hole B: APC/XCB to 350 mbsf with nonmagnetic core barrels and orientation (APC only) Hole C: RCB to 950 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole C: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Turbiditic/contouritic mud alternating with hemipelagic biogenic mud

Site RSCR-15

Priority:	Alternate (for RSCR-02B)
Position:	73.920300°S, 174.598800°W
Water depth (m):	2475
Target drilling depth (mbsf):	1000
Approved maximum penetration (mbsf):	1000
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF13**) Deep-penetration seismic reflection: • Primary line: SP55748 on line IT17RS-303B (Figure **AF18**) • Crossing line: SP87580 on line IT17RS-319 (Figure **AF19**)
Objective(s):	• Obtain a near-continuous post-RSU3 (mid-Miocene to Pleistocene?) and pre-RSU3 (mid-Miocene to Pliocene) sediment sequence to provide a high-resolution chronology and an ice-distal record of glacial/interglacial cycles • Recover a high-resolution record for correlation to inner and outer shelf records and mid- to high latitude deep-sea records of glacial and environmental change • Reconstruct Antarctic Slope Current vigor and Ross Sea Bottom Water production
Drilling program:	Hole A: APC to 250 mbsf with nonmagnetic core barrels, orientation (Icefield tool), and APCT-3 Hole B: APC/XCB to 350 mbsf with nonmagnetic core barrels and orientation (APC only) Hole C: RCB to 1000 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole C: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Turbiditic/contouritic mud alternating with hemipelagic biogenic mud

Site RSCR-16B

Priority:	Alternate
Position:	70.59171889°S, 172.91573501°E
Water depth (m):	2340
Target drilling depth (mbsf):	950
Approved maximum penetration (mbsf):	950
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF20**) Deep-penetration seismic reflection: • Primary line: CDP5750 on line NBP9702-06A (Figure **AF21**)
Objective(s):	• Obtain a near-continuous post-RSU3 (mid-Miocene to Pleistocene?) and pre-RSU3 (mid-Miocene to Pliocene) sediment sequence to provide a high-resolution chronology and an ice-distal record of glacial/interglacial cycles • Recover a high-resolution record for correlation to inner and outer shelf records and mid- to high latitude deep-sea records of glacial and environmental change • Reconstruct Antarctic Slope Current vigor and Ross Sea Bottom Water production
Drilling program:	Hole A: APC to 250 mbsf with nonmagnetic core barrels, orientation (Icefield tool), and APCT-3 Hole B: APC/XCB to 350 mbsf with nonmagnetic core barrels and orientation (APC only) Hole C: RCB to 950 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole C: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Drift deposits

Site RSCR-17A

Priority:	Alternate
Position:	70.799113°S, 174.70677°E
Water depth (m):	2350
Target drilling depth (mbsf):	500
Approved maximum penetration (mbsf):	500
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF20**) Deep-penetration seismic reflection: • Primary line: CDP11630 on line NBP9702-06A (Figure **AF22**)
Objective(s):	• Obtain a near-continuous post-RSU3 (mid-Miocene to Pleistocene?) and pre-RSU3 (mid-Miocene to Pliocene) sediment sequence to provide a high-resolution chronology and an ice-distal record of glacial/interglacial cycles • Recover a high-resolution record for correlation to inner and outer shelf records and mid- to high latitude deep-sea records of glacial and environmental change • Reconstruct Antarctic Slope Current vigor and Ross Sea Bottom Water production
Drilling program:	Hole A: APC to 250 mbsf with nonmagnetic core barrels, orientation (Icefield tool), and APCT-3 Hole B: APC to 250 mbsf with nonmagnetic core barrels and orientation; XCB to 500 mbsf
Downhole measurements program:	Hole C: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Drift deposits

Site RSCR-18A

Priority:	Alternate
Position:	73.910571°S, 162.456325°W
Water depth (m):	3650
Target drilling depth (mbsf):	650
Approved maximum penetration (mbsf):	650
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF23**) Deep-penetration seismic reflection: • Primary line: SP9000 on line TAN0602-04P4 (Figure **AF24**)
Objective(s):	• Obtain a near-continuous Pliocene/late Miocene? to present sediment sequence to provide a high-resolution chronology and an ice-distal record of glacial/interglacial cycles • Recover a high-resolution record for correlation to inner and outer shelf records and mid- to high latitude deep-sea records of glacial and environmental change • Reconstruct Antarctic Slope Current vigor and Ross Sea Bottom Water production
Drilling program:	Hole A: APC to 250 mbsf with nonmagnetic core barrels, orientation (Icefield tool), and APCT-3 Hole B: APC to 250 mbsf with nonmagnetic core barrels and orientation Hole C: XCB to 650 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole C: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Drift sediments

Site RSCR-19A

Priority:	Alternate
Position:	70.327650°S, 164.70000°W
Water depth (m):	4250
Target drilling depth (mbsf):	920
Approved maximum penetration (mbsf):	Requesting 1265 mbsf
Survey coverage (track map; seismic profile):	Bathymetric sketch and site track map (Figure **AF25**) Deep-penetration seismic reflection: • Primary line: CDP6950 on line AWI-20100107 (Figure **AF26**)
Objective(s):	• Obtain a near-continuous Eocene to present sediment sequence to provide a high-resolution chronology and an ice-distal record of glacial/interglacial cycles • Recover a high-resolution record for correlation to inner and outer shelf records and mid- to high latitude deep-sea records of glacial and environmental change • Reconstruct Antarctic Slope Current vigor and Ross Sea Bottom Water production
Drilling program:	Hole A: APC to 250 mbsf with nonmagnetic core barrels, orientation (Icefield tool), and APCT-3 Hole B: APC to 250 mbsf with nonmagnetic core barrels and orientation; XCB to 500 mbsf Hole C: RCB to 920 mbsf with nonmagnetic core barrels
Downhole measurements program:	Hole C: triple combo, FMS-sonic, and VSI
Nature of rock anticipated:	Drift sediments

Figure AF1. Contoured bathymetric maps showing location of proposed alternate Site EBOCS-08A on seismic reflection Profiles NBP0301-34B (Figure **AF2**) and NBP0301-09A (Figure **AF3**) and alternate Site EBOCS-09A on seismic reflection profile Line NBP0301-06A (Figure **AF2**). Contour interval = 250 m.

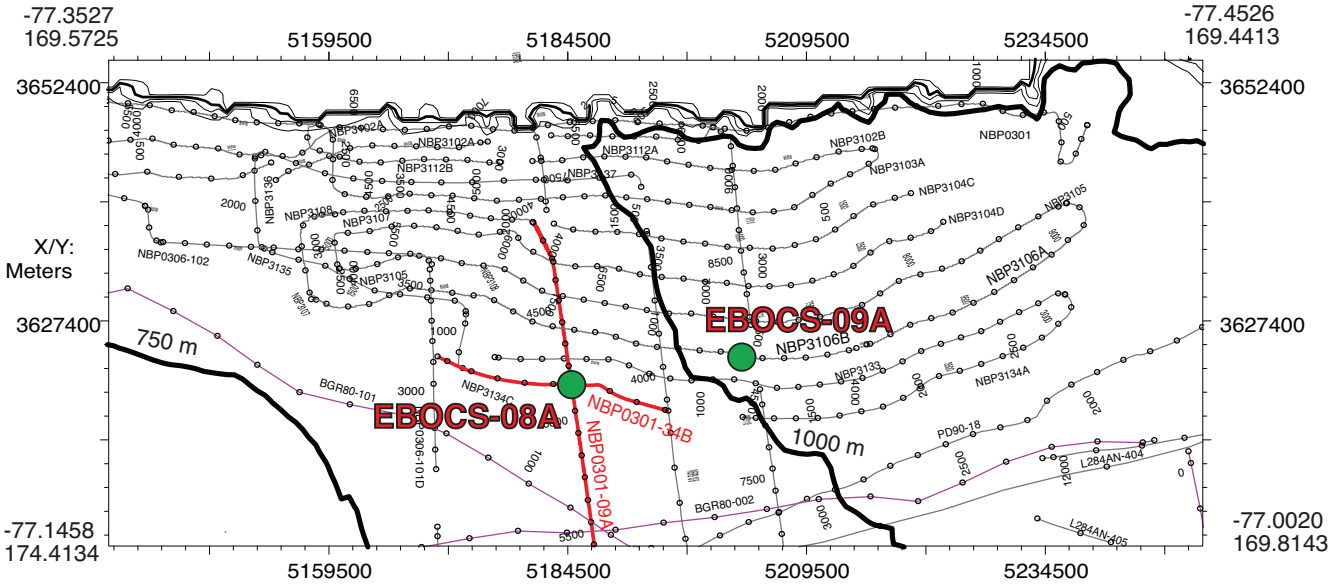


Figure AF2. Seismic reflection profile Line NBP0301-34B with location of proposed alternate Site EBOCS-08A (77.242528°S, 172.36400°E; SP437; water depth = 672 m; target depth = 1000 mbsf; approved maximum penetration = 1000 mbsf). SP = shotpoint.

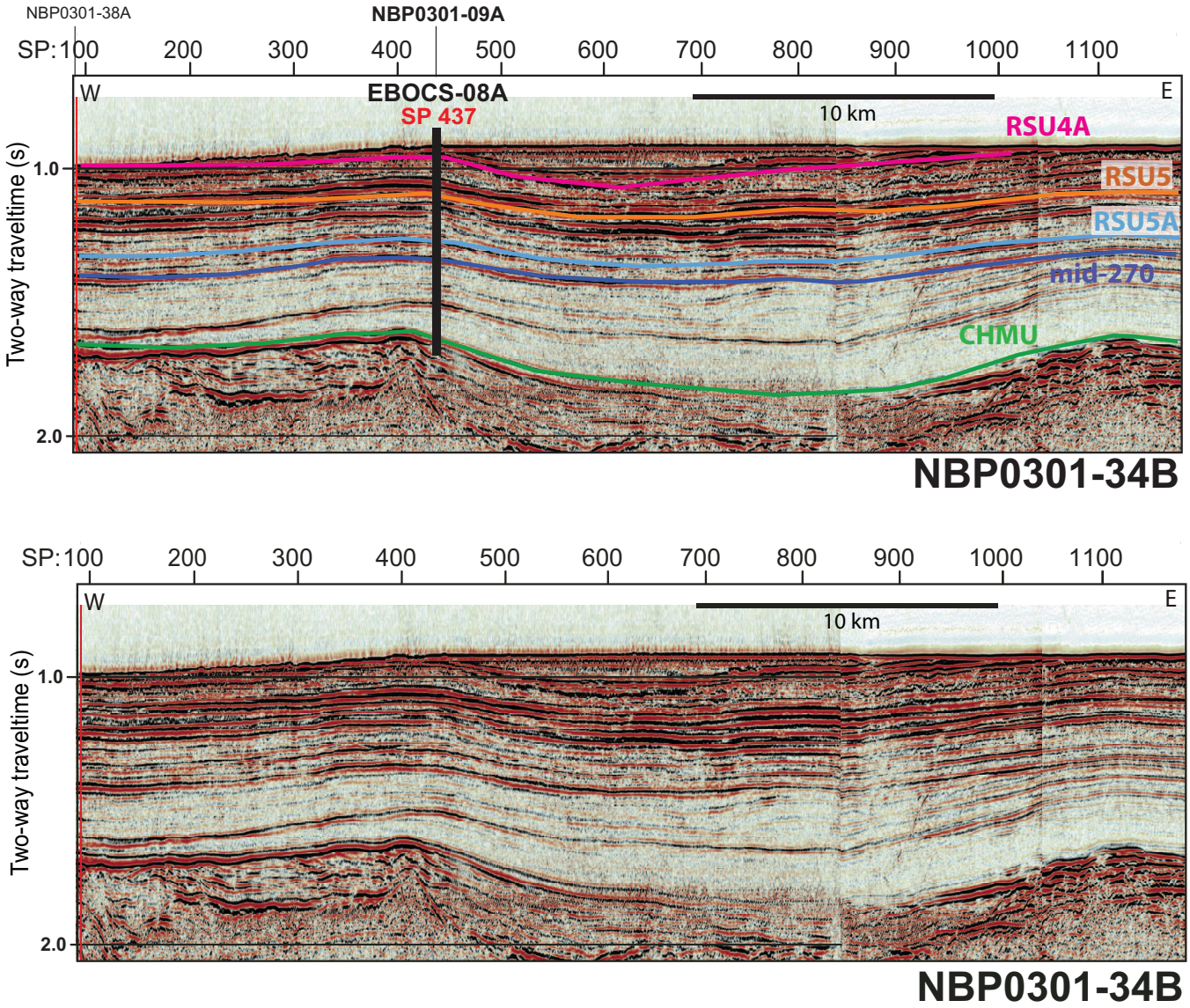


Figure AF3. Seismic reflection profile Line NBP0301-09A with location of proposed alternate Site EBOCS-08A (77.242528°S, 172.36400°E; SP4886; water depth = 672 m; target depth = 1000 mbsf; approved maximum penetration = 1000 mbsf).

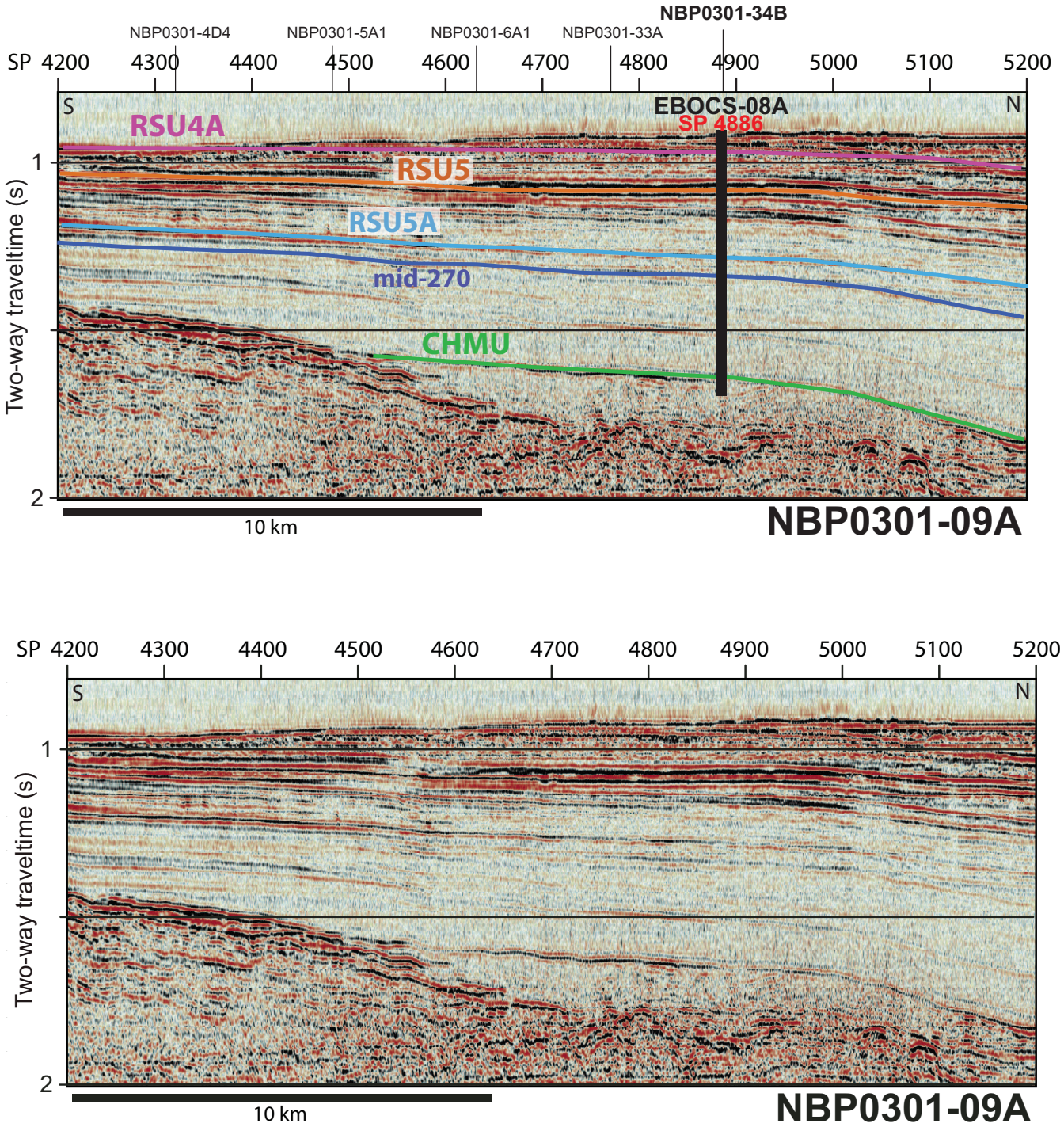


Figure AF4. Seismic reflection profile Line NBP0301-06A with location of proposed alternate Site EBOCS-09A (77.247108°S, 171.622215°; SP600; water depth = 764 m; target depth = 1300 mbsf; approved maximum penetration = 1300 mbsf).

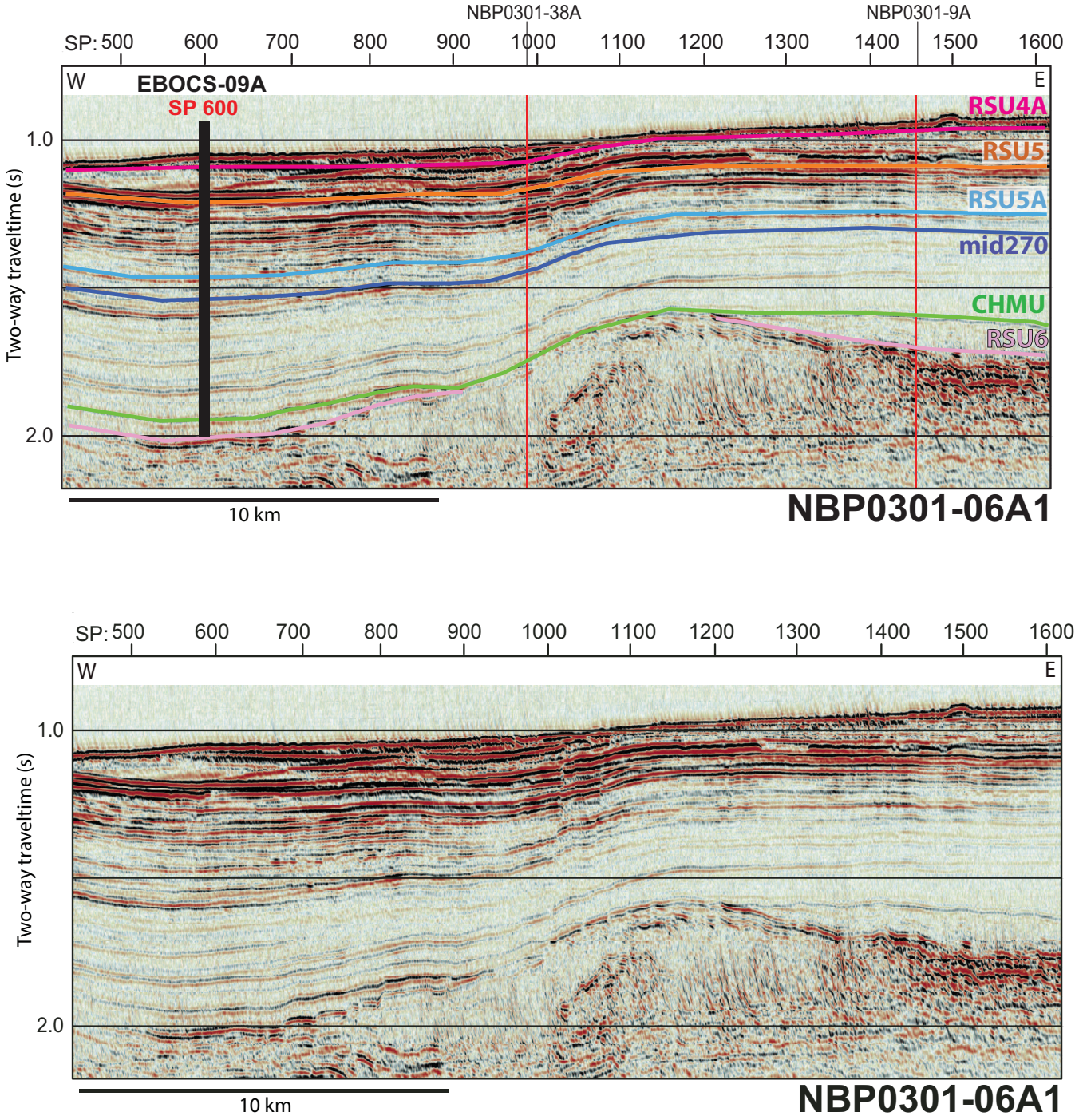


Figure AF5. Contoured bathymetric map showing location of proposed alternate Site EBOCS-11A on seismic reflection Profiles BGR80-001 (Figure **AF6**) and TH91-25SMG (Figure **AF7**).

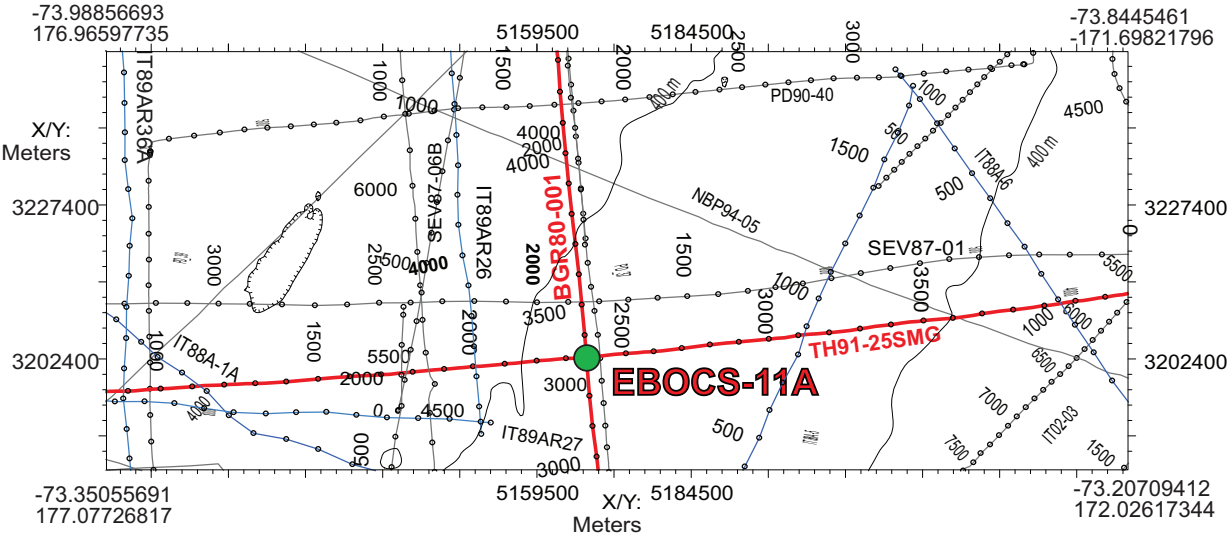


Figure AF6. Seismic reflection profile Line BGR80-001 with location of proposed alternate Site EBOCS-11A (73.49652175°S, 174.6760289°E; SP3327; water depth = 380 m; target depth = 520 mbsf; approved maximum penetration = 520 mbsf).

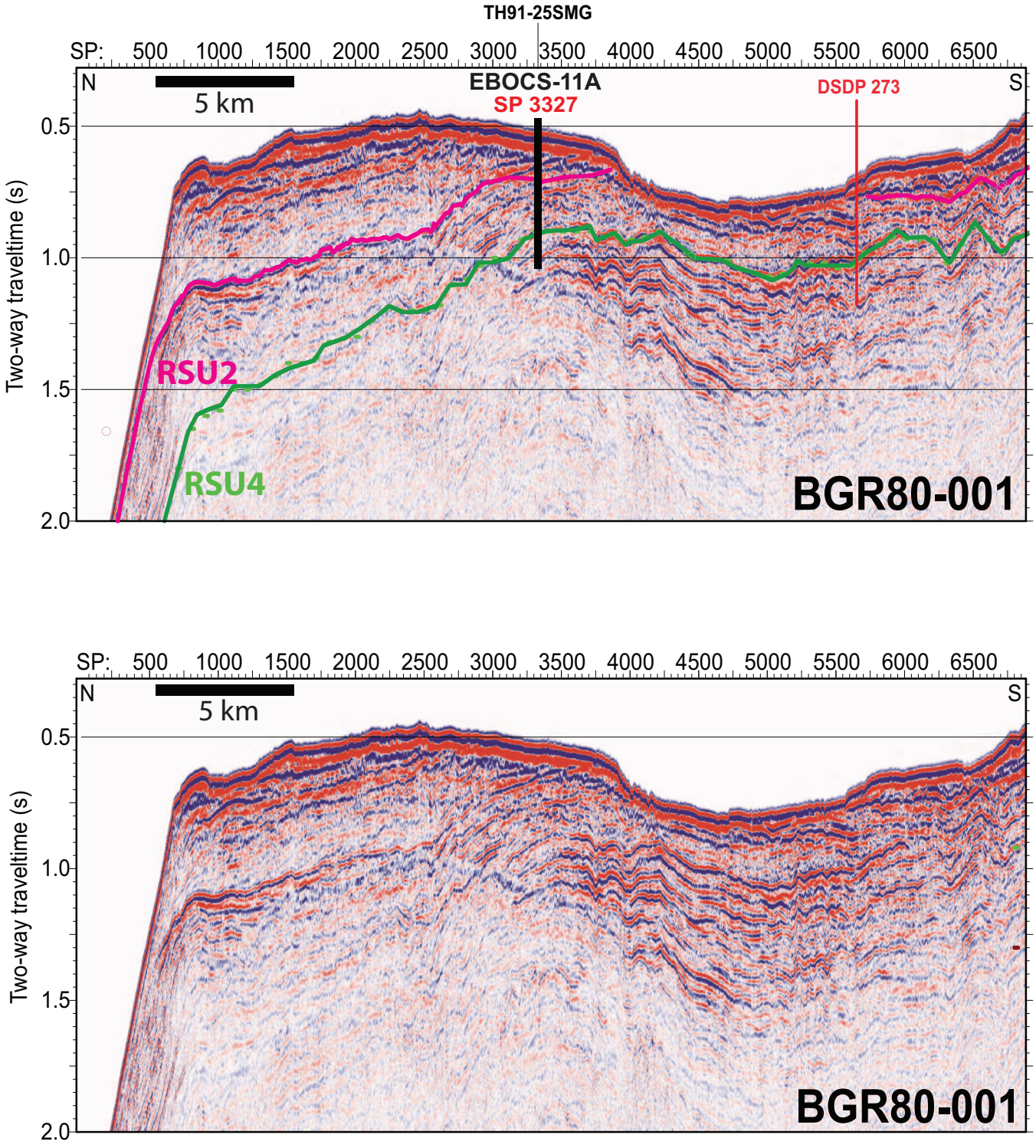


Figure AF7. Seismic reflection profile Line TH91-25SMG with location of proposed alternate Site EBOCS-11A (73.49652175°S, 174.6760289°E; SP2365; water depth = 380 m; target depth = 520 mbsf; approved maximum penetration = 520 mbsf).

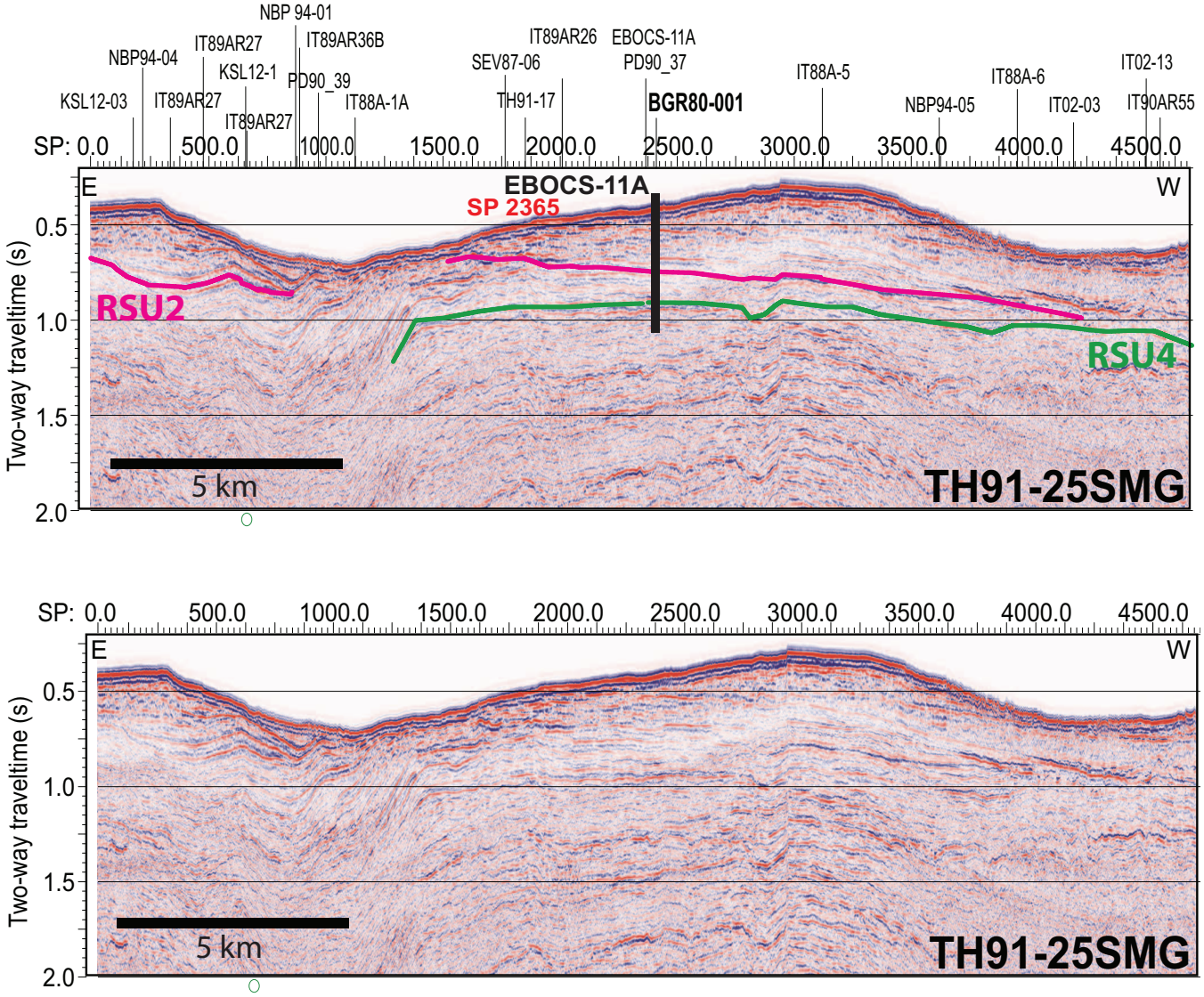


Figure AF8. Contoured bathymetric map showing location of proposed alternate Site EBOCS-12A on seismic reflection Profiles BGR80-001 (Figure **AF9**) and TH91-26SMG (Figure **AF12**) and proposed alternate Site EBOCS-13A on seismic reflection Profiles IT91A-86 (Figure **AF11**) and TH91-26SMG (Figure **AF12**). Contour interval = 250 m.

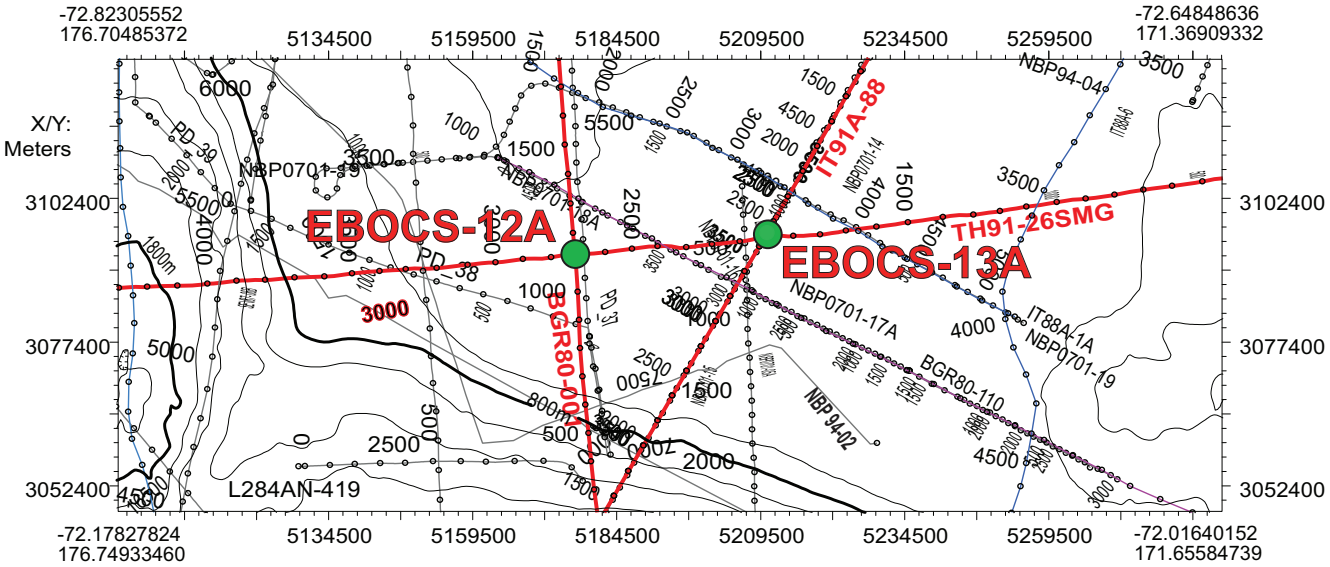


Figure AF9. Seismic reflection profile Line BGR80-001 with location of proposed alternate Site EBOCS-12A (72.50159422°S, 174.6883478°E; SP1128; water depth = 489 m; target depth = 1050 mbsf; approved maximum penetration = 1050 mbsf) and Deep Sea Drilling Project (DSDP) Site 273.

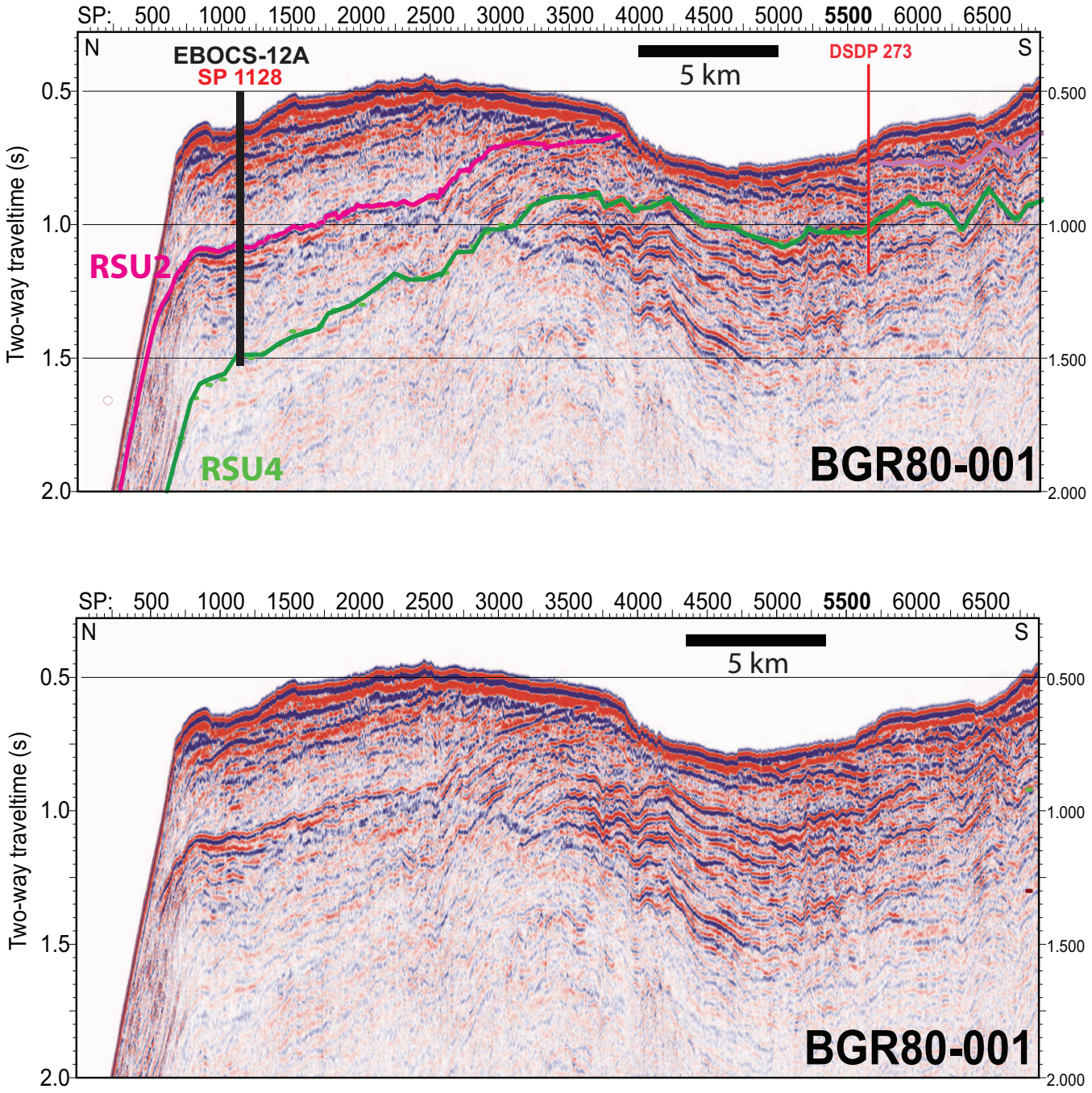


Figure AF10. Seismic reflection profile Line TH91-26SMG with location of proposed alternate Site EBOCS-12A (72.50159422°S, 174.6883478°E; SP2709; water depth = 489 m; target depth = 1050 mbsf; approved maximum penetration = 1050 mbsf).

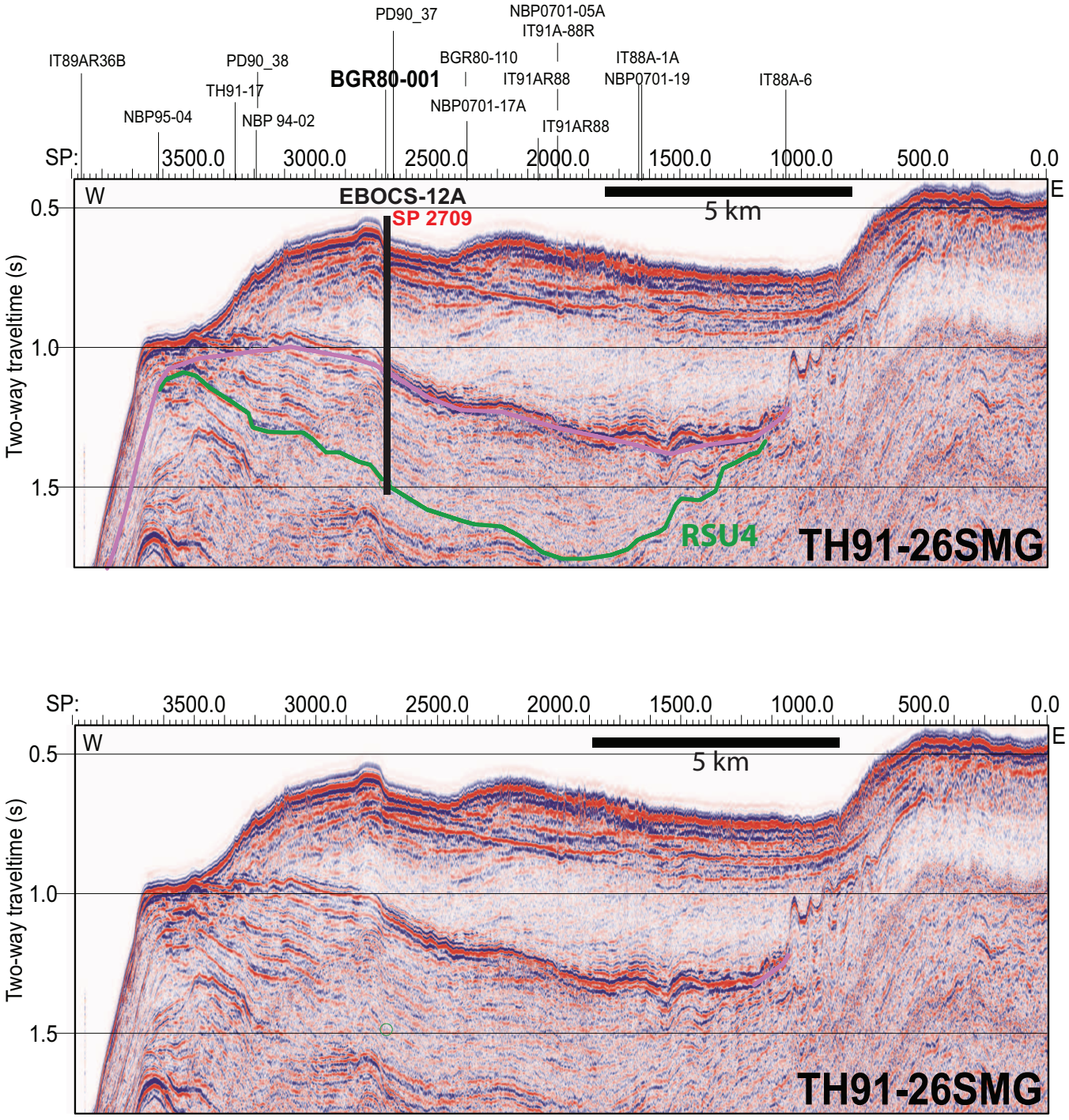


Figure AF11. Seismic reflection profile Line IT91A-88 with location of proposed alternate Site EBOCS-13A (72.5046448°S, 173.6860300°E; SP2645; water depth = 460 m; target depth = 1150 mbsf; approved maximum penetration = 1150 mbsf).

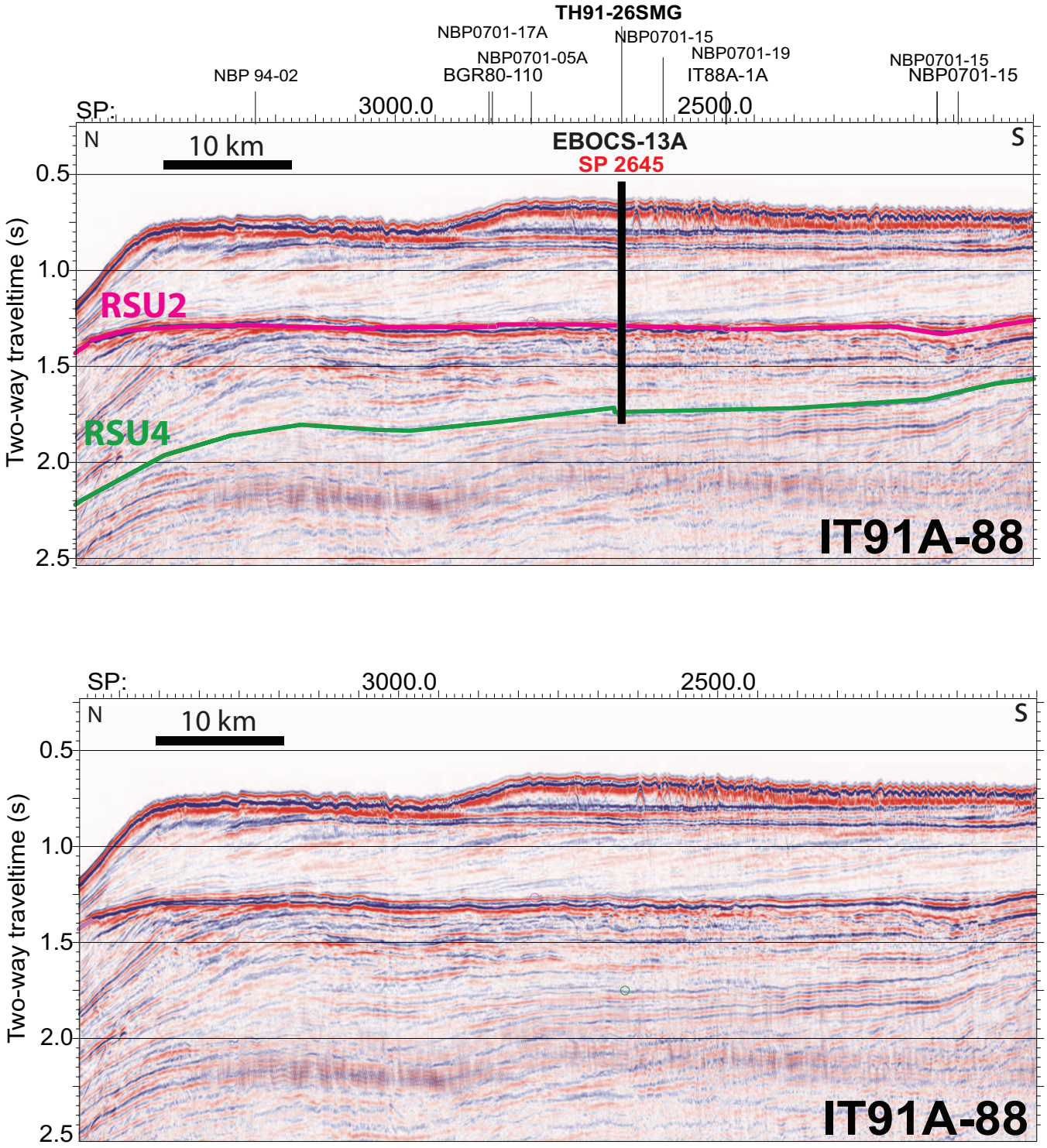


Figure AF12. Seismic reflection profile Line TH91-26SMG with location of proposed alternate Site EBOCS-13A (72.5046448°S, 173.6860300°E; SP2003; water depth = 460 m; target depth = 1150 mbsf; approved maximum penetration = 1150 mbsf).

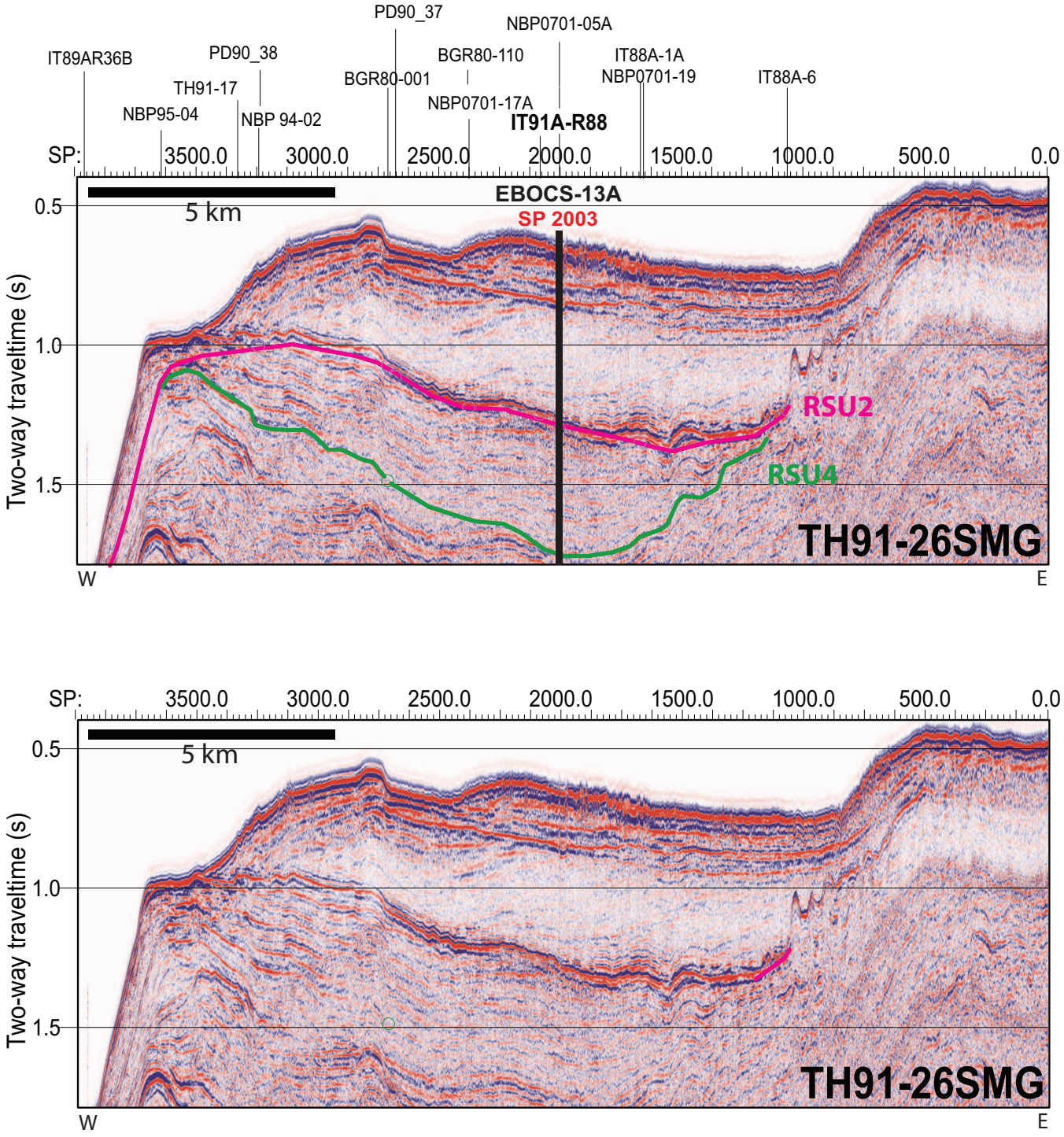


Figure AF13. Contoured bathymetric map showing locations of proposed alternate Sites RSCR-13B, RSCR-14A, and RSCR-15A. RSCR-13B is located on seismic reflection Profiles IT17RS-318 (Figure **AF14**) and IT17RS-302 (Figure **AF15**), RSCR-14A is located on seismic reflection Profiles IT17RS-301 (Figure **AF16**) and IT94AR-127A (Figure **AF17**), and RSCR-15A is located on seismic reflection Profiles IT17RS-303B (Figure **AF18**) and IT17RS-319 (Figure **AF19**). Contour interval = 250 m.

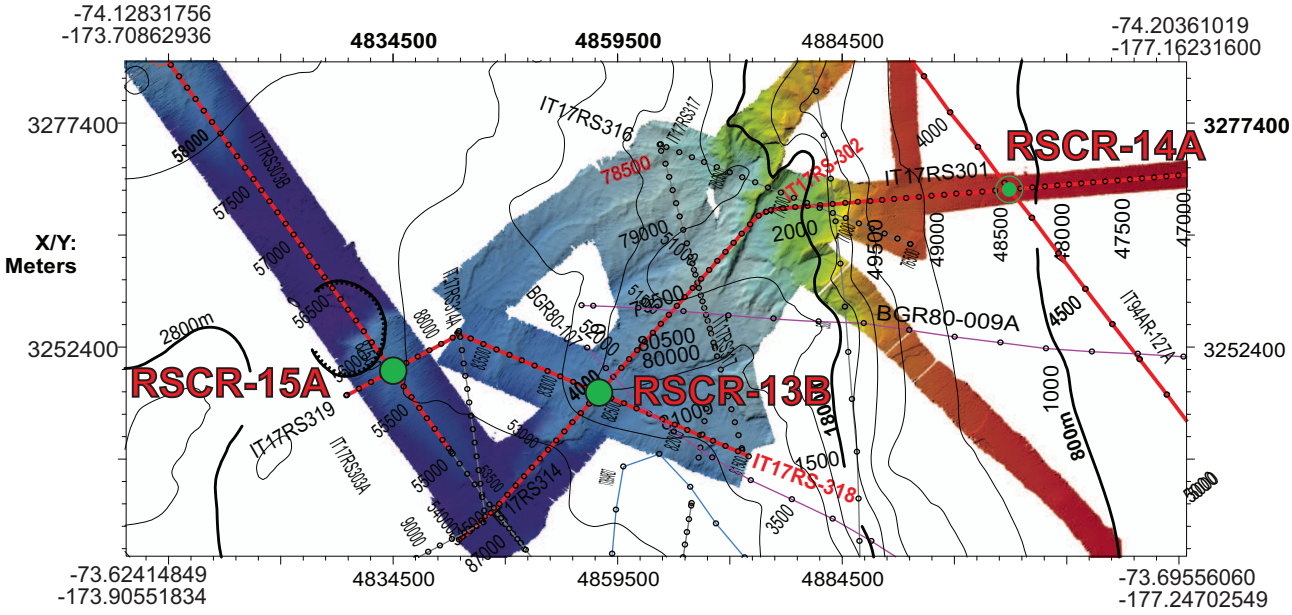


Figure AF14. Seismic reflection profile Line IT17RS-318 with location of proposed alternate Site RSCR-13B (73.9175423°S, 175.349974°W; SP82597; water depth = 2390 m; target depth = 1000 mbsf; approved maximum penetration = 1000 mbsf).

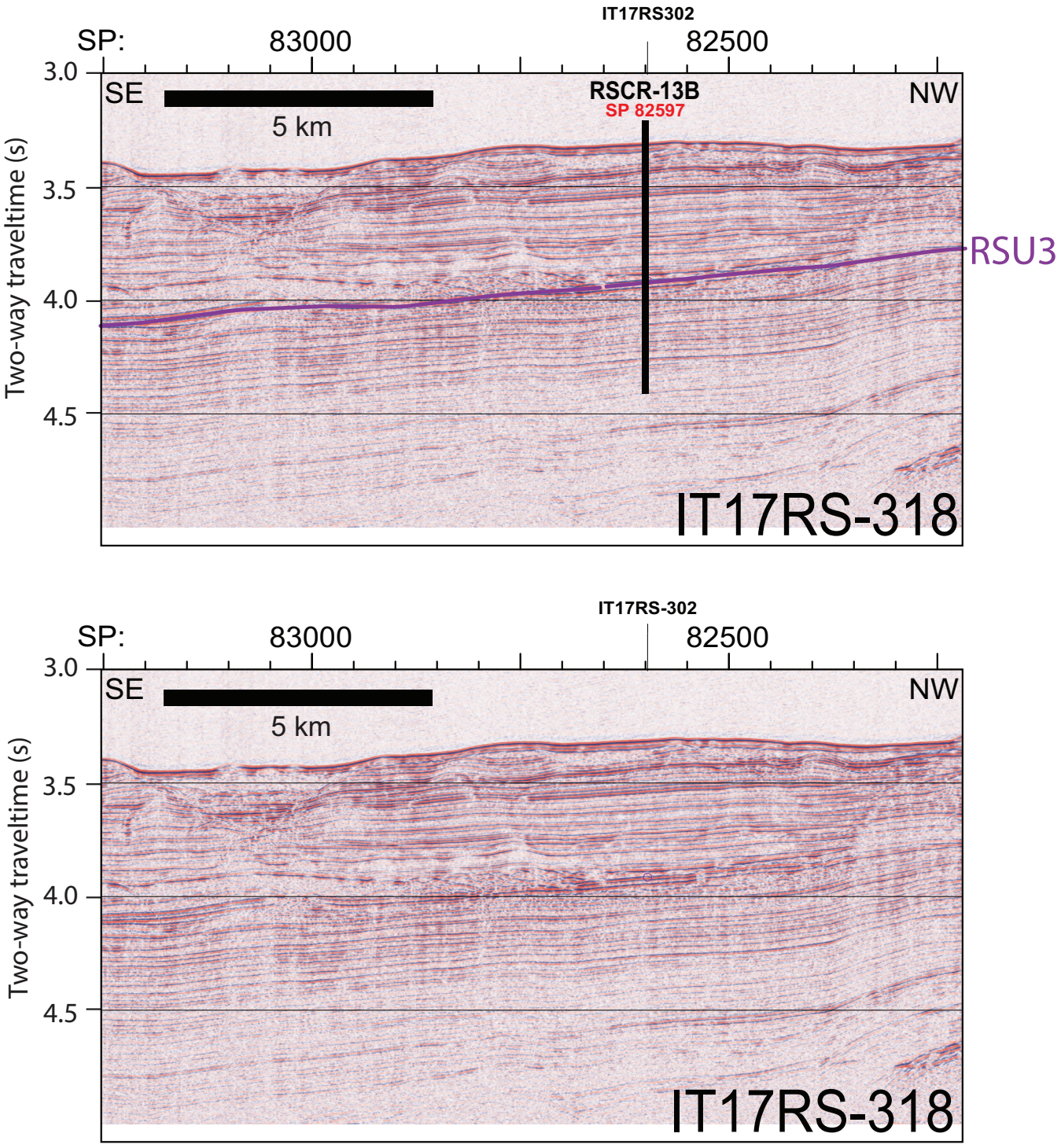


Figure AF15. Seismic reflection profile Line IT17RS-302 with location of proposed alternate Site RSCR-13B (73.9175423°S, 175.349974°W; SP52382; water depth = 2390 m; target depth = 1000 mbsf; approved maximum penetration = 1000 mbsf).

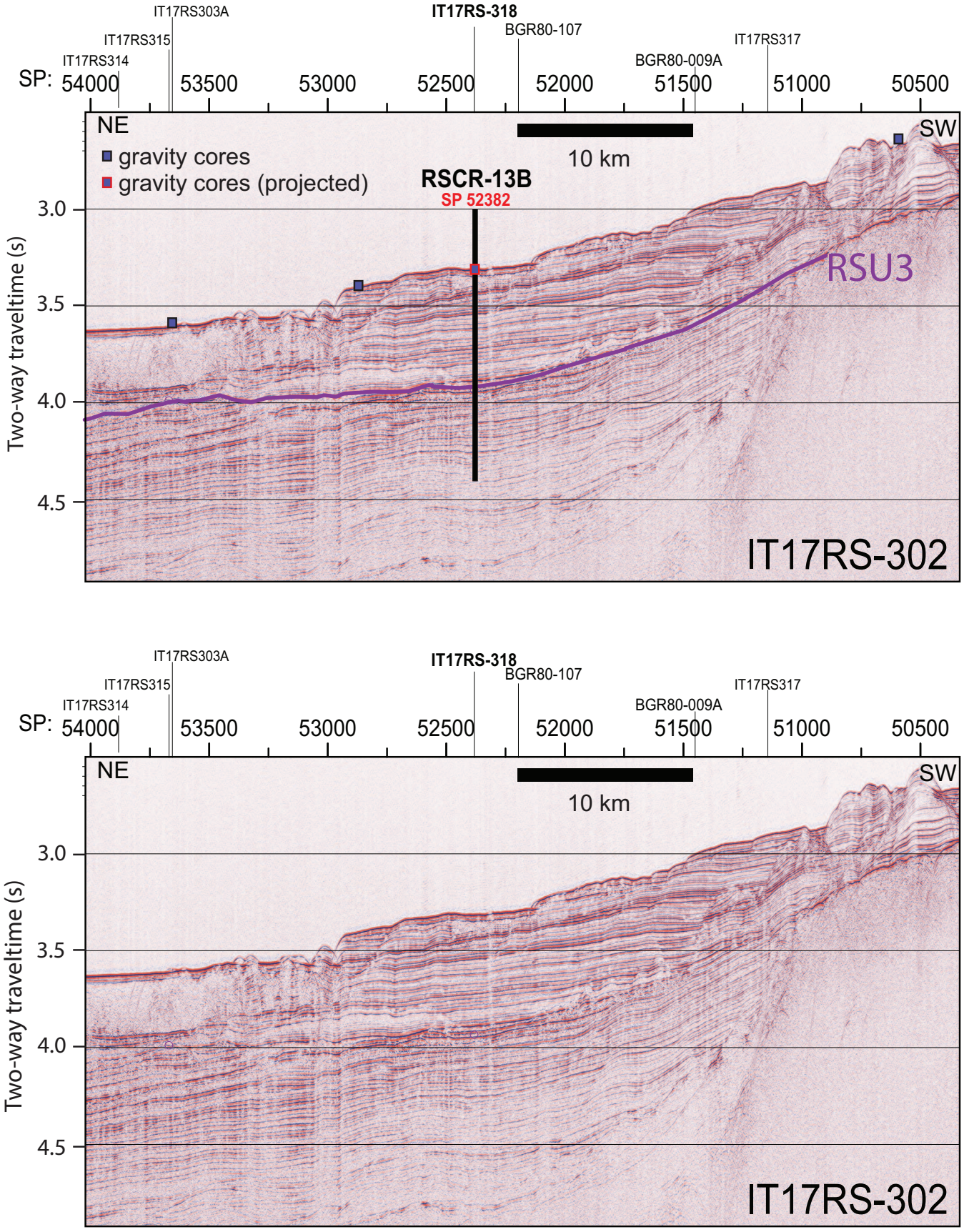


Figure AF16. Seismic reflection profile Line IT17RS-301 with location of proposed alternate Site RSCR-14A (74.1502999°S, 176.795129°W; SP48387; water depth = 810 m; target depth = 950 mbsf; approved maximum penetration = 950 mbsf).

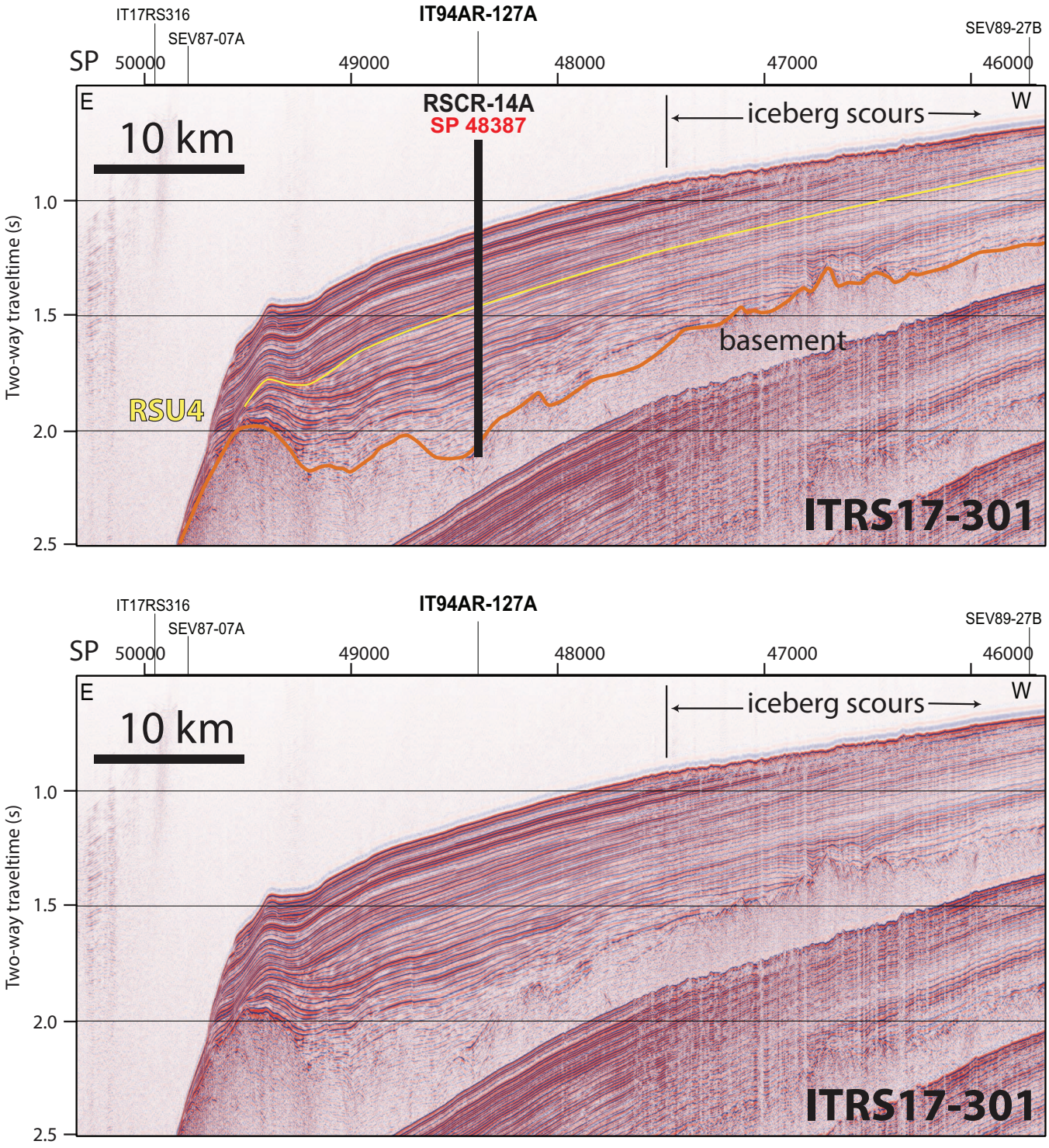


Figure AF17. Seismic reflection profile Line IT94AR-301 with location of proposed alternate Site RSCR-14A (74.1502999°S, 176.795129°W; SP4218; water depth = 810 m; target depth = 950 mbsf; approved maximum penetration = 950 mbsf).

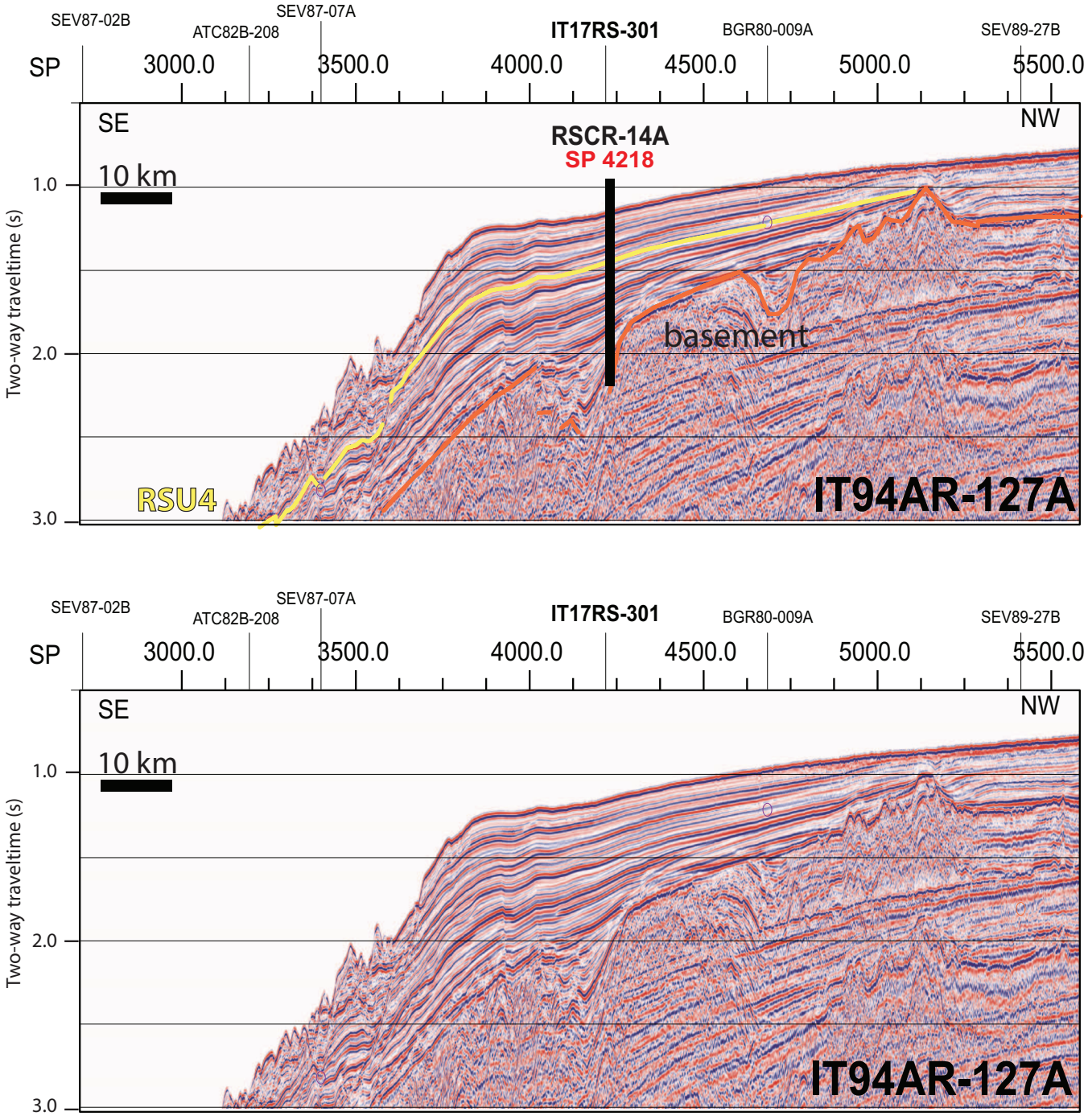


Figure AF18. Seismic reflection profile Line IT17RS-303B with location of proposed alternate Site RSCR-15A (73.920300°S, 174.598800°W; SP55748; water depth = 2475 m; target depth = 1000 mbsf; approved maximum penetration = 1000 mbsf).

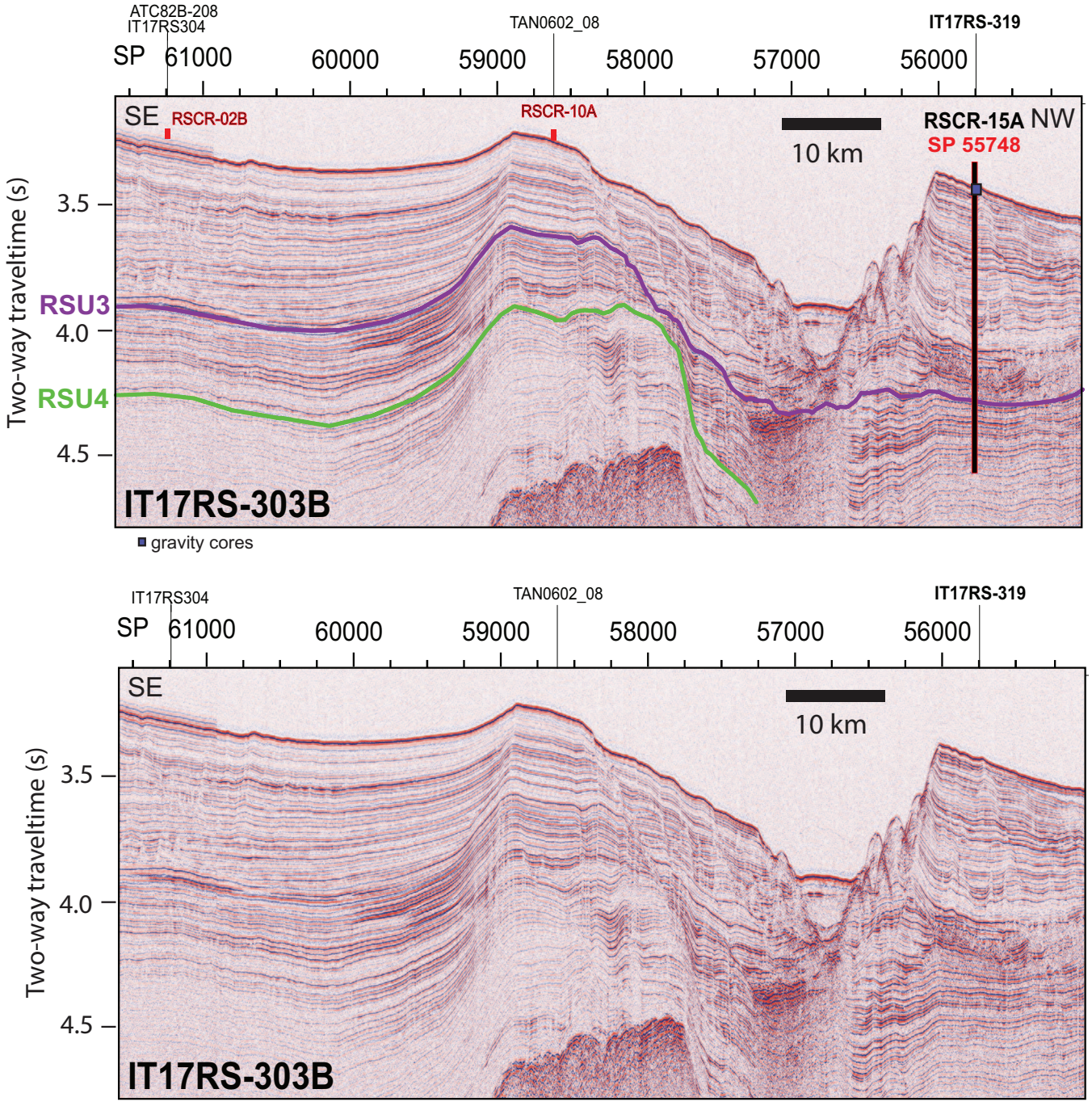


Figure AF19. Seismic reflection profile Line IT17RS-319 with location of proposed alternate Site RSCR-15A (73.920300°S, 174.598800°W; SP87580; water depth = 2475 m; target depth = 1000 mbsf; approved maximum penetration = 1000 mbsf).

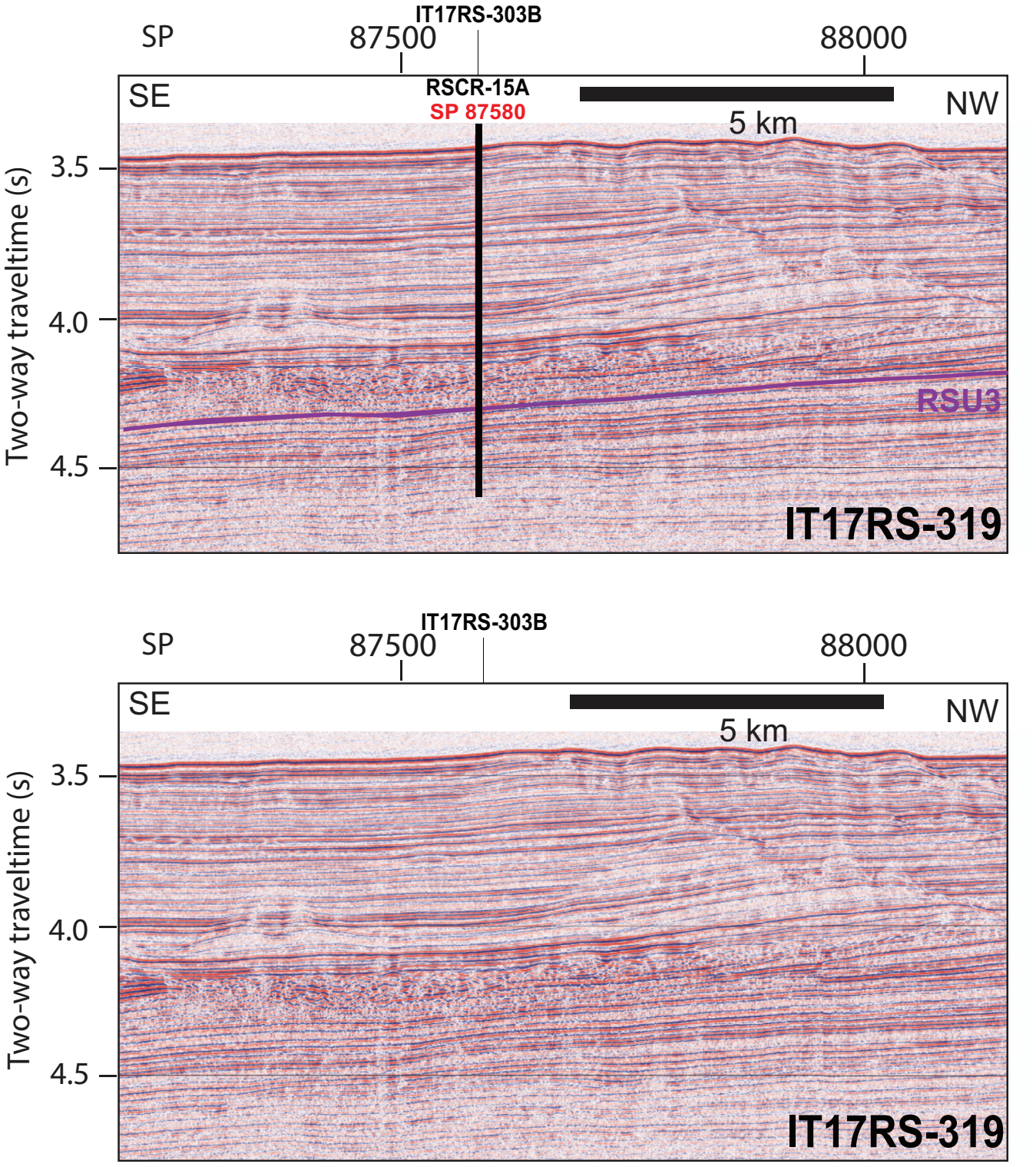


Figure AF20. Contoured bathymetric map showing location of proposed alternate Site RSCR-16B on seismic reflection Profile NBP9702-06A (Figure **AF21**) and proposed alternate Site RSCR-17A on seismic reflection Profile NBP9702-06A (Figure **AF22**).

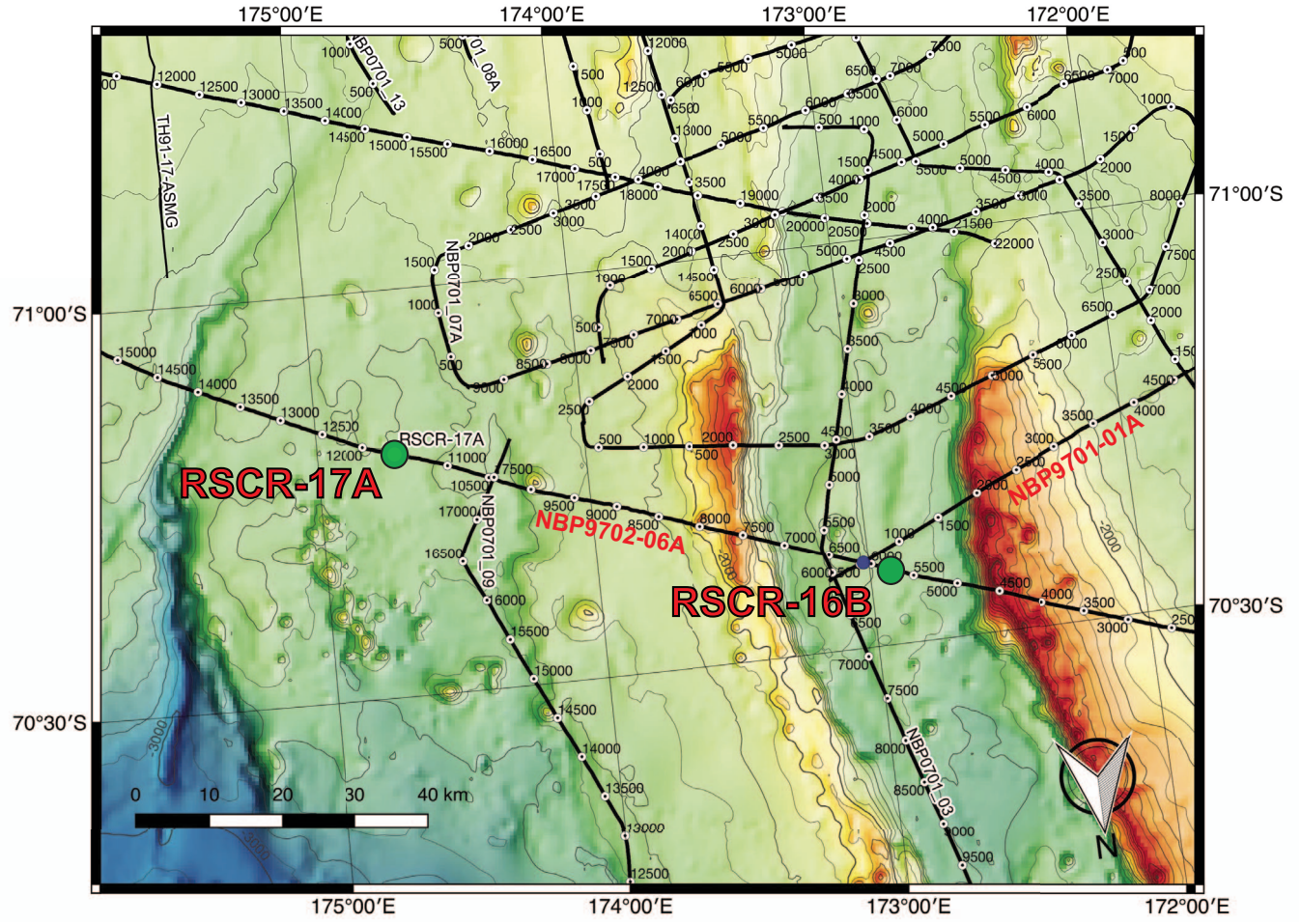
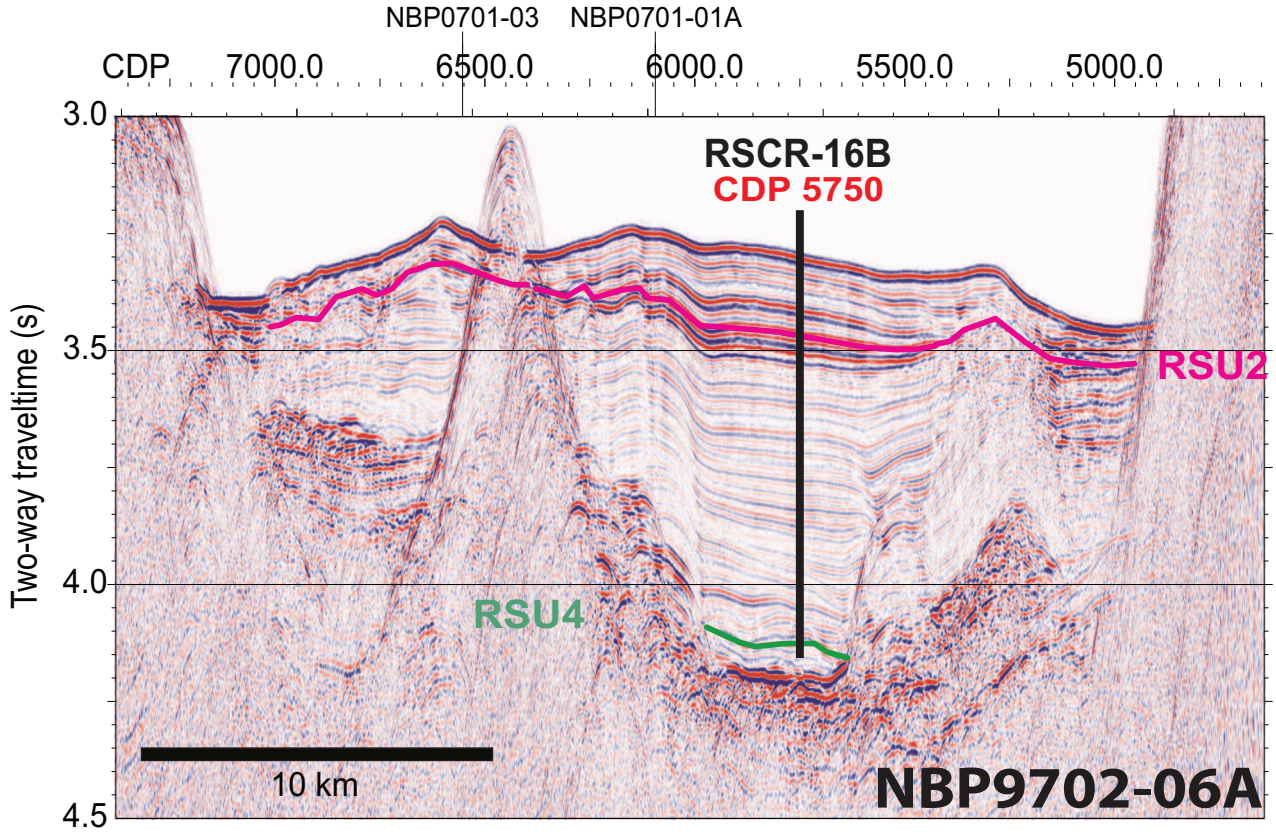


Figure AF21. Seismic reflection profile Line NBP9702-06A with location of proposed alternate Site RSCR-16B (70.59171889°S, 172.91573501°E; CDP5750; water depth = 2340 m; target depth = 950 mbsf; approved maximum penetration = 950 mbsf). CDP = common depth point.



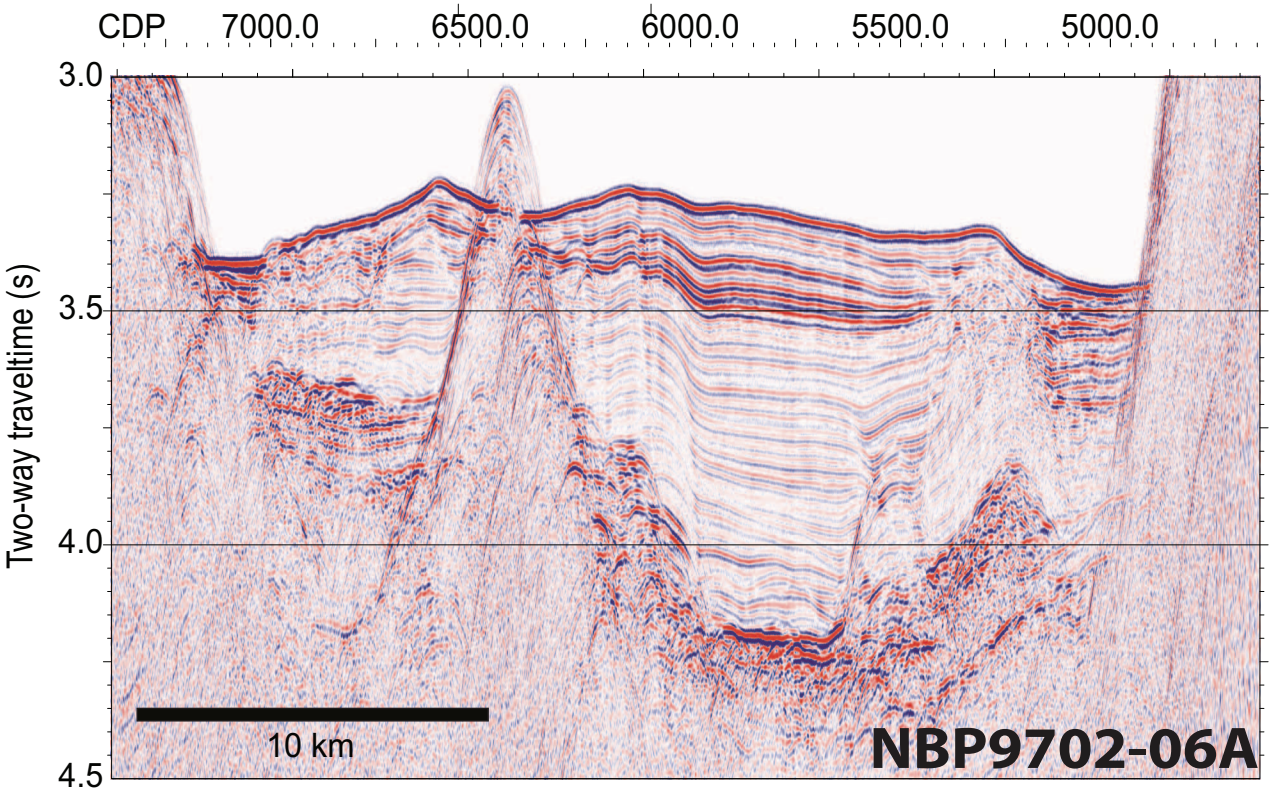


Figure AF22. Seismic reflection profile Line NBP9702-06A with location of proposed alternate Site RSCR-17A (70.799113°S, 174.70677°E; CDP11630; water depth = 2350 m; target depth = 500 mbsf; approved maximum penetration = 500 mbsf).

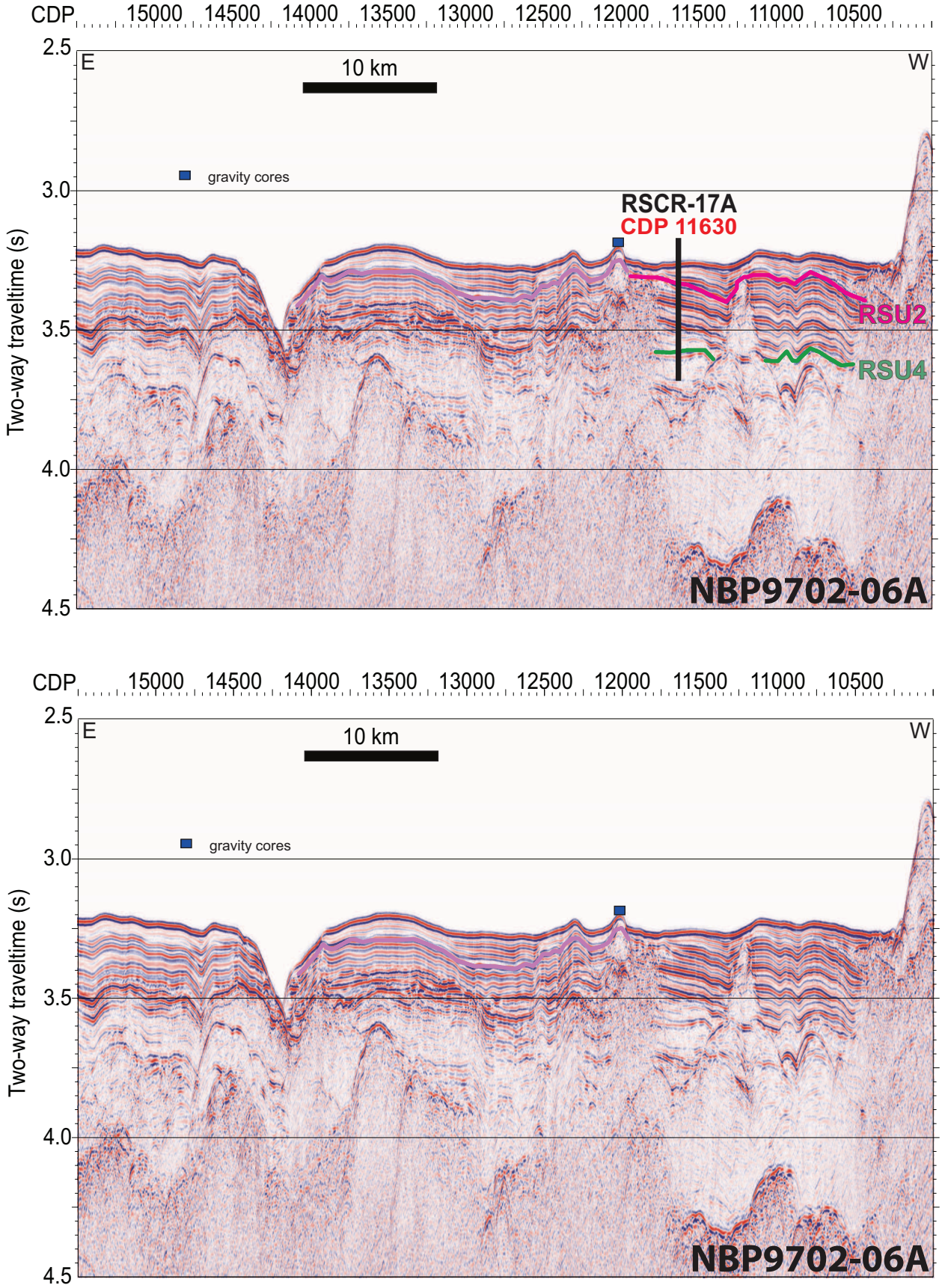


Figure AF23. Contoured bathymetric map showing location of proposed alternate Site RSCR-18A on seismic reflection Profile TAN0602-04P4 (Figure **AF24**). Contour interval = 500 m.

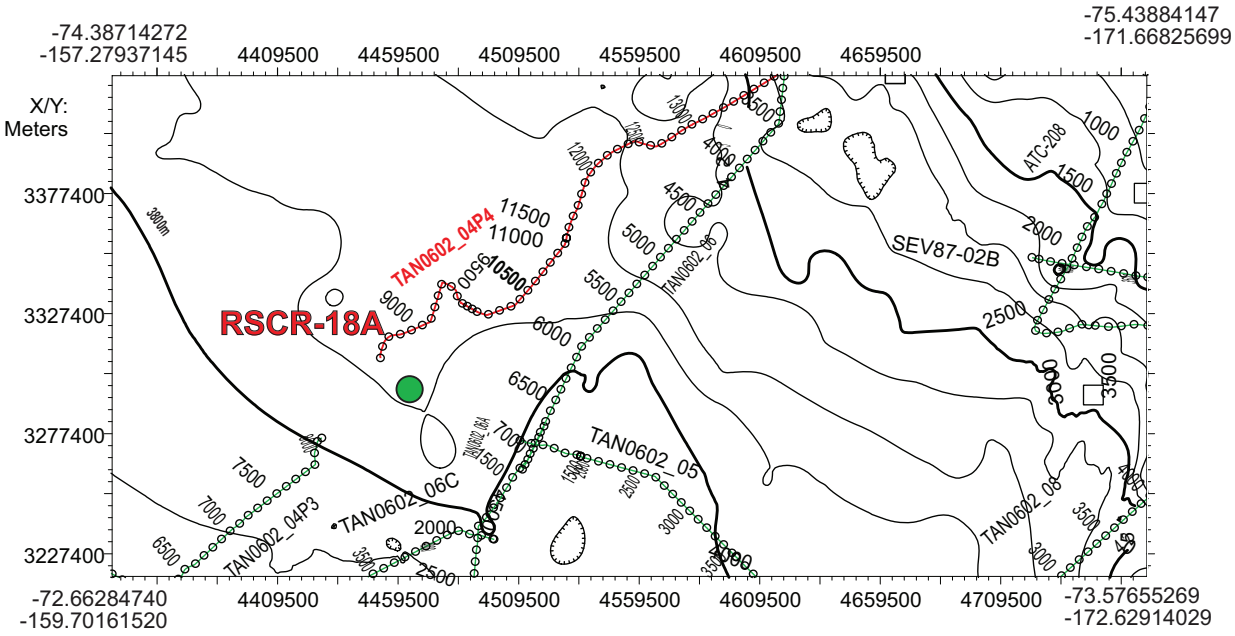


Figure AF24. Seismic reflection profile Line TAN0602-04P4 with location of proposed alternate Site RSCR-18A (73.910571°S, 162.456325°W; SP9000; water depth = 3650 m; target depth = 650 mbsf; approved maximum penetration = 650 mbsf).

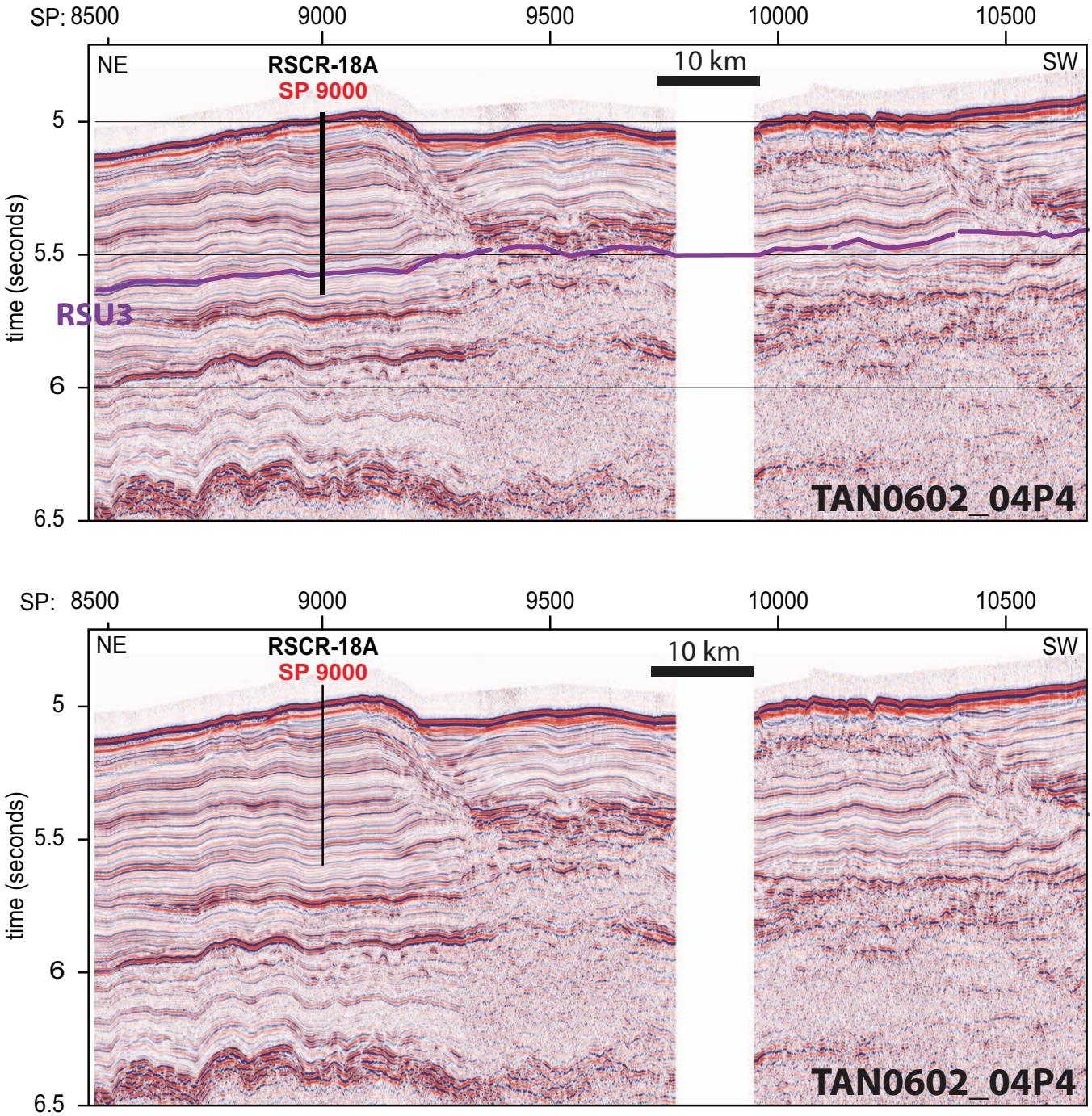


Figure AF25. Contoured bathymetric map showing location of proposed alternate Site RSCR-19A on seismic reflection Profile AWI-20100107 (Figure **AF26**). Contour interval = 250 m.

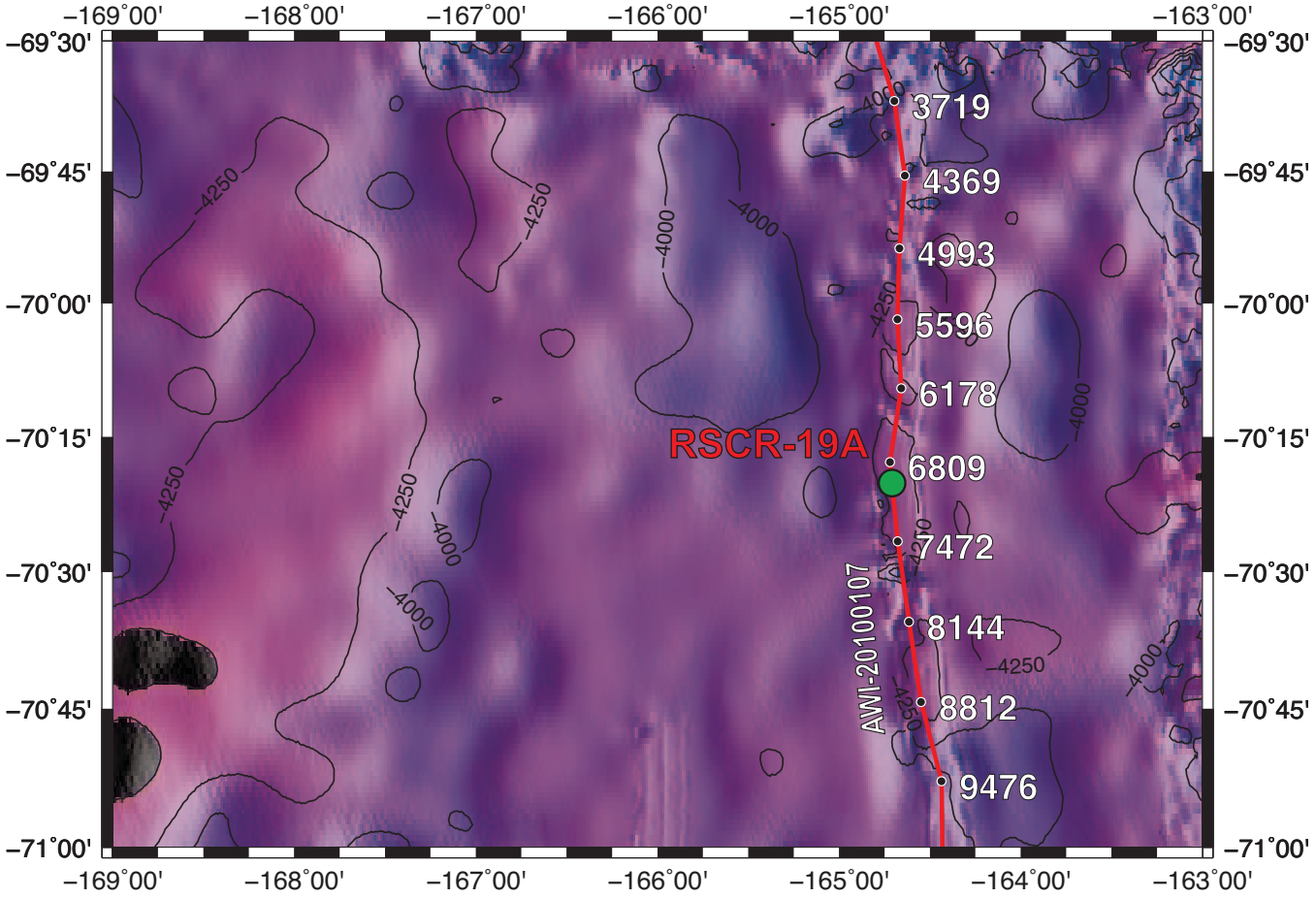


Figure AF26. Seismic reflection profile Line AWI-20100107 with location of proposed alternate Site RSCR-19A (70.327650°S, 164.70000°W; CDP6950; water depth = 4250 m; target depth = 920 mbsf; approved maximum penetration = to be determined).