International Ocean Discovery Program Expedition 372 Scientific Prospectus

Creeping Gas Hydrate Slides and LWD for Hikurangi Subduction Margin: coring and logging while drilling to unravel the mechanisms of creeping landslides and subduction slow slip events at the Hikurangi subduction margin, New Zealand

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Abstract

International Ocean Discovery Program (IODP) Expedition 372 combines two research topics, slow slip events (SSEs) on subduction faults (IODP Proposal 781A-Full) and actively deforming gas hydrate–bearing landslides (Proposal 841-APL). Our study area on the Hikurangi margin east of New Zealand provides unique locations for addressing both research topics.

Gas hydrates have long been suspected of being involved in seafloor failure; not much evidence, however, has been found to date for gas hydrate–related submarine landslides. Solid, icelike gas hydrate in sediment pores is generally thought to increase seafloor strength, as confirmed by a number of laboratory measurements. Dissociation of gas hydrate to water and overpressured gas, on the other hand, may destabilize the seafloor, potentially causing submarine landslides.

The Tuaheni Landslide Complex on the Hikurangi margin shows evidence for active, creeping deformation. Intriguingly, the landward edge of creeping coincides with the pinchout of the base of gas hydrate stability (BGHS) on the seafloor. We therefore hypothesize that gas hydrate may be linked to creeping by (1) repeated small-scale sliding at the BGHS, in a variation of the conventional model linking gas hydrates and seafloor failure; (2) overpressure at the BGHS due to a permeability reduction linked to gas hydrates, which may lead to hydrofracturing, weakening the seafloor and allowing transmission of pressure into the gas hydrate stability zone; or (3) icelike viscous deformation of gas hydrates in sediment pores, similar to onshore rock glaciers. The latter two processes imply that gas hydrate itself is involved in creeping, constituting a paradigm shift in relating gas hydrates to submarine slope failure. Alternatively, creeping may not be related to gas hydrates but instead be caused by repeated pressure pulses or linked to earthquake-related liquefaction. We have devised a coring and logging program to test our hypotheses.

SSEs at subduction zones are an enigmatic form of creeping fault behavior. At the northern Hikurangi subduction margin (HSM), they are among the best-documented and shallowest on Earth. They recur about every 2 y and may extend close to the trench, where clastic and pelagic sediments about 1.0–1.5 km thick overlie the subducting, seamount-studded Hikurangi Plateau. The northern HSM thus provides an excellent setting to use IODP capabilities to discern the mechanisms behind slow slip fault behavior, as proposed in IODP Proposal 781A-Full.

The objectives of Proposal 781A-Full will be implemented across two related IODP expeditions, 372 and 375. Expedition 372 will undertake logging while drilling (LWD) at three sites targeting the upper plate (midslope basin, proposed Site HSM-01A), the frontal thrust (proposed Site HSM-18A), and the subducting section in the trench (proposed Site HSM-05A). Expedition 375 will undertake coring at the same sites, as well as an additional seamount site on the subducting plate, and implement the borehole observatory objectives. The data from each expedition will be shared between both scientific parties. Collectively, the LWD and coring data will be used to (1) characterize the compositional, structural, thermal, and diagenetic state of the incoming plate and the shallow plate boundary fault near the trench, which comprise the protolith and initial conditions for fault zone rock associated with SSEs at greater depth, and (2) characterize the material properties, thermal regime, and stress conditions in the upper plate above the SSE source region. These data will be used during Expedition 375 to guide the installation of CORK observatories at the frontal thrust and in the upper plate above the SSE source to monitor temporal variations in deformation, fluid flow, seismicity, and physical and chemical properties throughout the SSE cycle (Saffer et al., 2017). Together, these data will test a suite of hypotheses about the fundamental mechanics and behavior of SSEs and their relationship to great earthquakes along the subduction interface.

Schedule for Expedition 372

Expedition 372 is based on two International Ocean Discovery Program drilling proposals. These include proposal numbers 841-APL2 (available at **http://iodp.tamu.edu/scienceops/precruise/hikurangislides/841-APL2.pdf**), 841-APL Add (available at **http://iodp.tamu.edu/scienceops/precruise/hikurangislides/841-Add.pdf**), 781A-Full (available at **http://iodp.tamu.edu/scienceops/precruise/hikurangimargin/781A-Full.pdf**), and 781A Add2 (**http://iodp.tamu.edu/scienceops/precruise/hikurangimargin/781A-Add2.pdf**). Expedition 372 will include the logging-while-drilling (LWD) operations proposed in 781A-Full. The remaining science operations outlined in proposal 781A-Full will be completed during Expedition 375: Hikurangi Subduction Margin (Saffer et al., 2017).

Following ranking by the IODP Scientific Advisory Structure, the expedition was scheduled for the research vessel (R/V) *JOIDES Resolution*, operating under contract with the JOIDES Resolution Science Operator (JRSO). At the time of publication of this *Scientific Prospectus*, the expedition is scheduled to start on 26 November 2017 in Fremantle, Australia, and end on 4 January 2018 in Wellington, New Zealand. A total of 39 days will be available for the initial port call, transit, drilling, coring, and LWD measurements described in this report (Table **T1**; for the current detailed schedule, see **http://iodp.tamu.edu/scienceops**). Further details about the facilities aboard the *JOIDES Resolution* and the JRSO can be found at **http://iodp.tamu.edu/labs/ship.html**.

Introduction

Submarine landslides

Submarine landslides constitute a significant geohazard and modify seafloor morphology (Mulder and Cochonat, 1996). Although progress has been made in studying their causes (Solheim et al., 2005), the processes that control the evolution of submarine slides are still only partially understood.

It is generally thought that submarine slides occur as single catastrophic events leading to mobilization and downslope transport of source material (Mulder and Cochonat, 1996). The submarine Tuaheni Landslide Complex (TLC) east of New Zealand's North Island, however, exhibits features typical of active, slow-moving terrestrial earthflows that appear to be creeping rather than failing in single events (Mountjoy et al., 2009). Such creeping behavior is observed onshore in mudslides (or earthflows) in weak clay-bearing rock (Baum et al., 2003) and rock glaciers in ice-bounded sediments (Martin and Whalley, 1987). Intriguingly, at the TLC, the creeping appears to be linked to the feather edge of gas hydrate stability (FEGHS) where the base of gas hydrate stability (BGHS) pinches out at the seafloor (Mountjoy et al., 2014b). Based on the curvature of bottom-simulating reflectors (BSRs) in the study area and BSR pinch outs in the vicinity of the slides (Chiswell, 2005; Pecher et al., 2005, 2008), the FEGHS is predicted to be between 585 and 640 m water depth, which coincides with the upper limit of creeping interpreted from structural and geomorphic data (Figure **F1**).

At the FEGHS, gas hydrates, seafloor failure, and ocean change are critically intertwined (Phrampus and Hornbach, 2012). Because gas hydrate is known to strengthen sediments in short-term deformation tests, seafloor destabilization has been linked to hydrate dissociation, although there is no solid evidence for this process. We now suggest that the presence of gas hydrate itself may be implicated in creeping during long-term seafloor deformation.

In support of this hypothesis, we have launched a multistage international research campaign starting with 3-D seismic acquisition in 2014 and remote drilling using the Meeresboden-Bohrgerät 200 (MeBo) system in 2016. We will further advance understanding of the mechanisms by which gas hydrates may cause creeping via a combined coring and LWD campaign that will take place during Expedition 372.

Slow slip events

Slow slip events (SSEs) involve transient aseismic slip across a fault (lasting weeks to months) at a rate intermediate between the plate boundary displacement rate and the slip velocity required to generate seismic waves. Only since the advent of dense, plate boundary–scale geodetic networks in the last decade has the importance of these events as a significant mode of fault slip been recognized. The observation of SSEs and associated seismic phenomena at subduction megathrusts worldwide (see review in Schwartz and Rokosky, 2007) has ignited one of the most dynamic fields of research in seismology today (e.g., Rubinstein et al., 2010; Peng and Gomberg, 2010; Wech and Creager, 2011). Although SSEs appear to bridge the gap between typical earthquake behavior and steady, aseismic slip on faults, the physical mechanisms that lead to SSEs and their relationship to destructive, seismic slip on subduction thrusts are poorly known. This deficiency in our understanding of SSEs is partly due to the fact that most well-studied subduction zone SSEs (Cascadia, southwest Japan) occur too deep for high-resolution imaging or direct sampling of the source region. A notable exception is the northern HSM, New Zealand, where well-characterized SSEs occur every 2 years, over a period of 2–3 weeks at depths <5–15 km below the seafloor (Wallace and Beavan, 2010) (Figure **F2**). The close proximity of SSEs to the seafloor at northern Hikurangi makes it feasible to drill into, sample, collect logs, and conduct monitoring within and around the source area in the near-field. Their regularity and well-characterized short repeat interval allows monitoring over multiple SSE cycles, with the potential to document the spatial and temporal distribution of strain accumulation and release, as well as any associated hydrogeologic phenomena.

The objectives of Expedition 372 include collecting LWD data at three sites across the northern HSM. The LWD tools employed will provide data on lithologies, sonic properties, porosity, tectonic and formation hydrogeology, fault and wall rock microstructure, stress conditions, and in situ temperature and fluid pressure. Integration of LWD data with seismic reflection data and core data from Expedition 375 will enable us to characterize the compositional, structural, thermal, hydrogeological, chemical, and diagenetic states, as well as the stress regime, of the sedimentary and upper volcanic "inputs" section of the incoming plate, the shallow plate boundary fault near the trench, and the upper plate above the SSE source region. Data from the subduction inputs and frontal thrust sites will constrain the protolith and conditions up-dip of the subduction fault zone associated with SSEs at greater depth.

During Expedition 375 in 2018, the integrated log-core-seismic data will be used to identify borehole depth targets at the upper plate and frontal thrust sites for the installation of CORK observatories (Saffer et al., 2017). These observatories will span across the entire SSE source region and be used to monitor deformation, temperature, hydrogeology, and seismicity related to SSE cycles.

Background

Tectonic setting

At the northern Hikurangi margin, the Pacific plate subducts beneath eastern North Island, New Zealand, at a rate of 4.5–5.5 cm/y (Wallace et al., 2004) (Figure **F2**). The oceanic subducting plate comprises the Hikurangi Plateau, a rough-crust, seamount-studded large igneous province of Cretaceous age (120–90 Ma). The plateau is overlain by a Cenozoic to Mesozoic sedimentary sequence that thickens from ~1–1.5 km at northern Hikurangi to > 5 km thick at southern Hikurangi, south of ~40°S. The northern Hikurangi margin is therefore relatively sediment starved. This part of the margin is characterized by a mixed mode of spatially varying tectonic accretion and frontal tectonic erosion associated with subducting seamounts (Lewis et al., 1998; Collot et al., 2001; Pedley et al., 2010). The past subduction of seamounts may have an effect on fluid pressures at the plate interface (Bell et al., 2010; Ellis et al., 2015). A number of seamounts are present on the Pacific plate approaching the deformation front (e.g., Tūranganui Knoll [formerly Gisborne Knoll] and Puke Seamount) (Figures **F3**, **F4**). Where accretion occurs at northern Hikurangi, the margin is characterized by a narrow, steep (>10° taper angle) wedge geometry (Barker et al., 2009). The Hikurangi subduction thrust is identified as a décollement between an undeformed subducting sequence and a thrust-imbricated wedge. Barker et al. (2009) show that the interface lies <5–6 km below the seafloor 15–40 km from the trench. At the deformation front, the plate interface thrust is developed at about 5 km below sea level and about 2 km below the seabed, at least locally in the upper part of the Hikurangi Basement Sequence, thought to comprise volcaniclastics and/or chert/limestone rocks (Davy et al., 2008). The décollement position at northern Hikurangi is stratigraphically deeper than at the southern Hikurangi margin, where it is believed to occur in the inferred pelagic sequence above Paleogene carbonates (Barnes et al., 2010; Ghisetti et al., 2016).

Geologic setting of Tuaheni Landslide Complex

The TLC is situated on the upper slope of the Hikurangi margin (Figure **F1**). The outer shelf and upper slope is underlain by Quaternary shelf-edge clinoform sequences (Pedley et al., 2010). These clinoforms consist of wedge-shaped sedimentary packages characteristic of sea level cycle–controlled progradational deposits (e.g., Posamontier and Vail, 1988; Van Wagoner et al., 1988). The clinoform sequences are fine grained at the surface (Alexander et al., 2010) but are likely to contain a significant sand fraction at depth, as found for similar sequences in the vicinity (Barnes et al., 1991). Miocene and older rocks have been documented beneath the Quaternary sections; these sequences have been exposed at places following erosion and/or tectonic uplift (Barnes et al., 2002; Field et al., 1997; Mountjoy and Barnes, 2011).

Dissociation of gas hydrates has long been suspected to be involved in seafloor failure, mainly because of (1) "melting" of a potentially frame-supporting or cementing solid to water and (2) net-volume expansion leading to elevated pore pressure due to the generation of free gas (Kvenvolden, 1993; Mienert et al., 1998). Conversely, it has been implied that gas hydrate itself would strengthen sediments, as observed in a number of laboratory experiments (e.g., Priest et al., 2005; Winters et al., 2004). Most studies into the role of gas hydrates in seafloor instability have thus focused on the BGHS. A few more recent findings, however, indicate that gas hydrates may directly or indirectly contribute to seafloor weakening. Rock Garden, a ridge on the Hikurangi margin with a flat top flanked by BSRs, appears to be eroded at the predicted top of gas hydrate stability in the ocean (Pecher et al., 2005). It has been proposed that gas hydrate indirectly causes seafloor weakening because a reduction of permeability due to the presence of gas hydrate may lead to the buildup of overpressure and hydrofracturing of the seafloor (Crutchley et al., 2010; Ellis et al., 2010). Furthermore, although earlier laboratory tests suggest that gas hydrate itself, unlike ice, does not exhibit any viscous behaviour (Durham et al., 2003), laboratory measurements on sands from the Nankai Trough indicate that gas hydrates may facilitate long-term deformation (Miyazaki et al., 2011). At the TLC, we now see evidence that similar processes may occur in nature.

Previous drilling of the Tuaheni Landslide Complex

Two sites were drilled in April–May 2016 in the TLC to ~80 meters below seafloor (mbsf) during the R/V *Sonne* Voyage SO-247 using the robotic MeBo drilling system (Site GeoB20803 near TLC-01D; Site GeoB20831 at TLC-04B) (Huhn, 2016). A summary of the core description for Site GeoB20831 is given in Table **T2**.

Although the critical interval of a potential décollement for creeping at ~40 mbsf (see below) was not recovered with MeBo, the material above and below the décollement is different. Poor core recovery precluded pore water analysis for chlorinity as a gas hydrate proxy. MeBo drilling also allowed tying seismic reflections into borehole data, particularly confirming the presence of intact sequences below landslide debris.

Seismic studies, site survey data, and recent findings: Tuaheni Landslide Complex

Four key multichannel seismic (MCS) reflection data types are available in support of the TLC drilling program (Figure **F5**):

1. Deep penetration, high-fold seismic sections (Survey 05CM; up to 12 km streamer, 960 channels) collected for Crown Minerals (now part of the Ministry for Business, Innovation, and Employment [MBIE]) by Multiwave Geophysical aboard the motor vehicle *Pacific Titan* in 2005 (unpubl. data),
2. Low-fold (up to 48 channel, 12.5 m group spacing) data collected by New Zealand research institutes during two surveys in 2011 (TAN1114) (Barnes and TAN 1114 Scientific Party, 2011) and 2012 (TAN1213),
3. P-Cable 3-D seismic reflection survey collected during Survey TAN1404 (Mountjoy et al., 2014a), and
4. Low-fold high-resolution 2-D multichannel data acquired using the P-Cable seismic streamers (1.5 m group spacing) collected during Survey TAN1404 (Mountjoy et al., 2014a).

In addition, these site-specific data are supported by archived regional profiles acquired by the R/V *L'Atalante* in 1993 (Collot et al., 1996), the R/V *Tangaroa* in 1998 and 2001 (National Institute of Water and Atmospheric Research [NIWA] Cruises 3044 and Tan0106), and several oil exploration companies in the 1970s. Four ocean bottom seismometers (OBSs) were also deployed within the 3-D volume.

High-resolution (CHIRP) data are available in three types:

1. Pre-2015 Knudsen 3.5 kHz subbottom profiler data are available from *Tangaroa* Voyages TAN1114, TAN1213, and TAN1404. These data are of variable quality because the internally mounted Knudsen system did not acquire good data over areas of rough seafloor (e.g., landslide debris).
2. From 2015 onward, NIWA installed the externally mounted TOPAS PS 18 Parametric subbottom profiler on the *Tangaroa*. Data from this system are available for surveys.
3. Parasound profiles were acquired as part of *Sonne* Voyage SO247 preceding MeBo drilling. The Atlas Parasound P70 system with 70 kW transmission power emits two primary frequencies of 18 kHz (PHF, fixed) and 18.5–28 kHz (adjustable), thus generating parametric secondary frequencies in the range of 0.5–6 kHz (SLF) and 36.5–48 kHz (SHF) (Huhn, 2016). Data quality is comparable to the TOPAS PS 18.

Interpretation of the recently collected data, in particular the 3-D seismic cube, confirmed that, in general, the transition from compressional to extensional (creeping) regime coincides with the predicted FEGHS. Furthermore, a possible décollement for creeping was identified ~0.05 s two-way traveltime (TWT) beneath the seafloor (~40 mbsf) (Figure **F1**).

Slow slip events on the Hikurangi subduction margin

SSEs at the northern Hikurangi margin occur offshore of Gisborne township every 18–24 months and typically involve 1–2 cm of southeast surface displacement at continuous GPS (cGPS) sites (Figure **F2**) (Wallace and Beavan, 2010). The portion of the subduction interface that undergoes slow slip is completely "locked" between the SSEs, and this locking or "slip deficit" is essentially fully recovered by slip in repeating SSEs (Wallace and Beavan, 2010). Inversion of cGPS displacements from these SSEs indicate that the equivalent moment magnitudes are typically Mw 6.5–7.0, with average slip of ~7–15 cm on the plate interface. These larger SSEs are punctuated by more frequent, smaller events (one or more per year) that are not as well characterized (Figure **F2**; cGPS time series inset). SSEs occur near Gisborne beneath the offshore region, with the downdip limit of slip near the coastline and repeated SSE rupture of the same areas of the interface (Wallace and Beavan, 2010). A recent seafloor geodetic experiment has shown that slow slip occurs to within 2 km of the seafloor beneath the outer part of the proposed drilling transect, and possibly continues all the way to the trench (Figure **F4**) (Wallace et al., 2016).

MCS data reveal regions where the interface (between <5 and >10–16 km depth) follows the top of a 1–2 km thick high-amplitude reflectivity zone (HRZ) in the subducting plate (Figures **F2**, **F3**) (Bell et al., 2010). The January–February 2010 SSE coincided with the HRZ, whereas the subsequent 2010 March–April SSE source region lies within an intervening lower amplitude reflection zone. The high-amplitude reflectivity may be the result of high fluid concentrations within sediments, entrained between downgoing seamounts. Alternatively, the reflections may result from altered oceanic basaltic lavas and volcaniclastics of the subducted Hikurangi Plateau. If the former interpretation is correct, then the correlation between the HRZ and SSEs would suggest that fluids exert an important control on the generation of slow slip (Bell et al., 2010) by reducing effective stress (e.g., Kodaira et al., 2004; Liu and Rice, 2007; Audet et al., 2009; Song et al., 2009).

Previous drilling on the Hikurangi margin and northern Hikurangi seismic stratigraphy

There has been no previous scientific drilling at the HSM apart from shallow robotic MeBo drilling (Huhn, 2016). However, there have been 44 industry exploration wells drilled onshore and 3 offshore on the continental shelf east of North Island, targeting the Hikurangi forearc East Coast Basin. They range in penetration depth from <100 m to 4352 m. None of these wells are commercially productive. They provide insights into the stratigraphy and physical conditions that could be present beneath the upper margin at proposed Site HSM-01A but not at proposed Site HSM-18A where the frontal wedge is comprised of imbricated trench-fill section and lower slope cover sediments.

A previous Ocean Drilling Program (ODP) expedition targeted the eastern portion of the Hikurangi Plateau (Sites 1123 and 1124) (Carter et al., 2000). These core data tied to seismic profiles of the plateau by Davy et al. (2008) and correlated westward to the Hikurangi Trough by Barnes et al. (2010) allow inferences of the subduction inputs seismic stratigraphy (Figure **F3**).

Seismic studies and site survey data: northern Hikurangi subduction margin

Supporting site survey data for Expedition 372 are archived at the IODP Site Survey Data Bank (SSDB) (**https://ssdb.iodp.org/SSDBquery/SSDBquery.php**; select P781 or P841 for the proposal number). There are two types of 2-D MCS reflection data available in support of the subduction drilling objectives of the expedition (Figure **F4**): (1) deep penetration, high-fold (up to 12 km streamer, 960 channel) seismic sections (Survey 05CM) collected for Crown Minerals of New Zealand's Ministry for Economic Development (presently part of the MBIE) by Multiwave Geophysical aboard the *Pacific Titan* in 2005 (unpubl. data) and (2) low-fold (up to 48 channel) data collected by New Zealand and French research institutes on several surveys between 1998 and 2013. The most important of these academic data include regional and site survey lines collected specifically for this drilling project by NIWA and GNS Science aboard *Tangaroa* Surveys TAN1114 in 2011 and TAN1213 in 2013. These primary site-specific data are supported by archived regional profiles acquired by the *L'Atalante* in 1993 (Collot et al., 1996), the *Tangaroa* in 1998 and 2001 (NIWA Cruises 3044 and Tan0106) (Pedley et al., 2010), and several oil exploration companies in the 1970s.

The center line of the drilling transect (Profile 05CM-04; Figure **F3**), used to provide a regional interpretation of the margin and support subduction drilling sites, was acquired in 2005 as part of a regional grid of ~2800 line kilometers of 2-D seismic reflection data (Survey 05CM). These data were acquired by Multiwave Geophysical aboard the *Pacific Titan* using a source array of Bolt 1500 and 1900 long-life air guns in a combination of single guns and clusters, with a total volume of 4140 in^3. The calculated source signature has a fairly flat amplitude spectrum across the range ~6–100 Hz. The shot interval was 37.5 m, and the record length was 12 s TWT. The streamer specification was a 12 km long active section comprising 960 channels (12.5 m channel spacing). Data were processed to prestack time migration by Fugro. Seismic sections in the SSDB have 12.5 m common depth point (CDP) bins and are prestack time migrated. Surface-related multiple elimination (SRME) was achieved in the time domain on shot gathers and using a parabolic Radon transform on CDP gathers in the Tau-P domain to isolate multiple energy, which was then subtracted from the data. Velocities used for depth conversion of Line 05CM-04 were derived from normal moveout semblance analysis of SRME CDP gathers. The final seismic images of Line 05CM-04 (Figure **F3**) used to support proposed primary drilling Sites HSM-01A and HSM-05A and proposed frontal thrust Site HSM-15A (alternate for proposed primary Site HSM-18A) are time-to-depth conversions (05CM-04_PSTM_TDCONV.sgy) of the prestack time-migrated (05CM-04_PSTM.sgy) section. In addition, the shallow part of Line 05CM-04 has been reprocessed to preserve amplitudes of reflections and to provide higher lateral resolution (6.25 m CDP binning) (Navalpakam et al., 2012). The seismic data collected on *Tangaroa* surveys TAN1114 and TAN1213 support the proposed primary drilling Site HSM-18A and the eight other proposed alternate sites around proposed Sites HSM-18A, HSM-01A, and HSM-05A. These data were collected with a seismic source consisting of two 45/105 GI guns (total volume = 300 in^3) operated at 140 bar pressure, a typical shot interval of 25 m (10.8 s), and a 600 m long Geometrics Geoeel 48-channel streamer with receiver group interval of 12.5 m. The seismic data were processed to poststack time–migrated (finite-difference migration) sections with a 6.25 m CDP bin spacing, resulting in 12-fold stacks. The depth conversion of these sections at drilling site locations is based on the high-density velocity analysis derived from Line 05CM-04.

The regional and drilling site seismic reflection data are supported by full margin-wide coverage of 30 kHz multibeam echosounder data acquired with the Kongsberg EM300, Kongsberg EM302, and Atlas Hydrosweep MD-2/30 systems. The most important of these site details are the Kongsberg EM302 data collected in 2011. This system was operated with 288 fully stabilized beams and a 1-degree along-track by 2-degree across-track footprint. The processed data at drilling sites have been reduced to produce a 25 m grid digital elevation model of the seafloor.

Scientific objectives

Tuaheni Landslide Complex: hypotheses and scientific objectives

The TLC is thought to have initially formed as a catastrophic submarine slide (the parent slide), followed by ongoing slow deformation of the slide mass. The lower-edge of the slide mass is unconfined. Morphology and images of faults in seismic data shows compressional features in the upper part of the slide mass, whereas the lower part shows extensional features. Furthermore, the slide mass is flanked by elongated strike-slip faults. These observations point toward a conveyor-belt model for slow deformation sediment movement through the slides, where sediments are being supplied into the upper slide mass, leading to compression, and are being removed at the toe of the TLC, similar to mudslides and rock glaciers on land (Mountjoy et al., 2009).

It was originally suggested that slow deformation in the TLC reflects repeated small-scale seafloor failure associated with localized charging and discharging of pore pressure (Mountjoy et al., 2009) without involvement of gas hydrates. This process would lead to successions of small-scale compressional and extensional features.

We have, however, observed a general switch from compressional to extensional regimes at about 600 m water depth with compression above and extension, indicating creeping, beneath it. This water depth coincides with the predicted FEGHS. We therefore hypothesize that gas hydrates may cause creeping in the TLC (Mountjoy et al., 2014b). We propose the following hypotheses that may link gas hydrates to creeping (Figure **F6**):

- Hypothesis 1: overpressure may lead to slow sliding at the BGHS, in a modification of conventional models linking gas hydrates to seafloor instability (Phrampus and Hornbach, 2012).
- Hypothesis 2: overpressure at the BGHS causes hydrofracturing, facilitating transmission of overpressure into the hydrate zone and sediment weakening, similar to mechanisms proposed for seafloor erosion on Rock Garden south of the study area (Pecher et al., 2005; Crutchley et al., 2010) ("hydrate pressure valve").
- Hypothesis 3: interstitial gas hydrates in sediments within the TLC slide mass may cause creeping deformation, perhaps because of icelike viscous behavior of hydrates ("hydrate glacier").

Antitheses (i.e., mechanisms that do not involve gas hydrates) include the following:

- Antithesis 1: creeping in the TLC could be caused by repeated small-scale failure associated with buildup and release of overpressure, the originally proposed mechanism behind creeping (Mountjoy et al., 2009).
- Antithesis 2: earthquake-related liquefaction of massive coarse silt beds, as detected during recent MeBo drilling, facilitates downslope movement.

We plan to distinguish between the proposed hypotheses based on lithology and evidence for fracturing, as well as profiles of gas hydrate saturation, pore pressure, and temperature. Creep mechanisms are predicted to have the following key manifestations:

- Hypothesis 1 (sliding at the BGHS): the key process controlling creeping would be elevated pressure at the BGHS. Temperature profiles will be important to reconstruct past pressure-temperature disturbances that may be causing ongoing gas hydrate dissociation and resulting overpressure.
- Hypothesis 2 (hydrate pressure valve): overpressure is present at the BGHS and transmitted into the gas hydrate stability zone. The presence of a fracture network above the BGHS allows transmission of pressure leading to overpressure at the décollement for creeping. No such fracture networks would be expected in the compressional part of the TLC.
- Hypothesis 3 (hydrate glacier): gas hydrate saturation would be expected to change across the décollement. Compressional and extensional parts of the slides would not show any significant differences in terms of pore pressure or fracturing.

The antitheses would not predict any anomalies linked to gas hydrate saturation, in particular no pressure disruption at the BGHS or fracture networks related to gas hydrates. The two proposed mechanisms would otherwise have different signatures:

- Antithesis 1 (repeated small-scale seafloor failure): elevated pore pressure is expected in the compressional regime (pressure charging) compared to the extensional zone (discharged).
- Antithesis 2 (liquefaction of coarse silt beds): cores might reveal localized shearing and liquefaction within the shear zone.

We plan to obtain the necessary data for distinguishing between our proposed creeping mechanisms by achieving the following objectives through drilling the TLC: (1) obtain lithologic information, (2) collect samples for shore-based laboratory studies, (3) constrain in situ gas hydrate saturation, (4) obtain pore pressure profiles, and (5) confirm the presence or absence of fracturing. These results will be used to (6) calibrate seismic reflection site survey data. We have selected a main site in the creeping part of the TLC (proposed primary Site TLC-04B; proposed alternate Sites TLC-01C and TLC-05B) for coring and LWD through the BGHS. Furthermore, we plan two LWD sites with coring as contingency in the compressional region of the TLC (proposed primary Site TLC-02C; proposed alternate Sites TLC-05C and TLC-06B) and within the gas hydrate stability field away from the TLC (proposed primary Site TLC-03B; proposed alternate Site TLC-07A).

TLC objective 1: obtain lithologic information within the creeping slides.

Coring is planned to obtain information on the lithology within the creeping, extensional part of the TLC and the underlying sediments. Our proposed primary site in the extensional regime, TLC-04B (Figure F7) was drilled to 80 mbsf with the MeBo in 2016 (Site GeoB20831) (Huhn, 2016), encountering deformed clayey silt in the upper 28 m and stiff clayey silt beneath 60 mbsf with good recovery. The lithology is expected to be similar to the base of the hole at 205 mbsf, beneath the BGHS. Between 28 and 60 mbsf, recovery with the MeBo's rotary drilling was poor, yielding disturbed very fine sandy coarse silt. A second MeBo site was drilled ~100 m from our proposed alternate Site TLC-01C (Site GeoB20831), yielding similar lithologies with poor recovery in the upper part of the hole. Recent analysis of the 3-D site survey indicates that a prominent reflection at ~40 mbsf acts as décollement for creeping (Mountjoy et al., 2016). MeBo drilling, although not successful at recovering material across this décollement, indicates that lithologies change across this horizon. Recovering cores across the proposed décollement for creeping is therefore a high priority using the *JOIDES Resolution*'s advanced piston corer (APC) system. Lithologic information will then be extrapolated using the seismic data.

TLC objective 2: collect samples for shore-based laboratory studies.

The microscopic distribution of gas hydrate in sediments and its interaction with the sediment frame may be highly dependent on porosity distribution and mineralogy, such as clay minerals. We therefore plan to test whether and how creeping may be linked to viscous behavior of the hydrate-sediment mix by conducting laboratory measurements on material recovered from the TLC. Sediments from APC and, potentially, pressure cores (see below) at our site in the extensional regime, proposed primary Site TLC-04B (proposed alternate Sites TLC-01C and TLC-05C) may be reconstituted followed by formation of gas hydrates. Alternatively, intact samples from the APC system may be used for hydrate formation. The focus of these studies will be on material in the creeping part of the section from above the proposed décollement, in particular the coarse-grained silts, with the aim to study the response of long-term deformation as a function of gas hydrate concentration and habitat.

TLC objective 3: constrain in situ gas hydrate saturation and composition.

Gas hydrate saturation with depth is a key parameter for all three proposed hydrate-related creep mechanisms. We plan to constrain profiles of gas hydrate saturation with depth based on LWD profiles, calibrated at the extensional site by pore water chlorinity in APC cores. Degassing of pressure cores will provide additional calibration of gas hydrate saturation and allow determination of the composition of the hydrate-forming gas mix. The gas mix is important for hydrate stability calculations and improved understanding of the general gas and gas hydrate system at the TLC.

TLC objective 4: obtain pore pressure and temperature profiles.

The hydrate pressure valve model and the model of sliding at the BGHS both involve pore pressure anomalies. Furthermore, the antithesis of repeated small-scale sliding at the BGHS without involvement of gas hydrates is predicted to have a characteristic pressure signature. We plan to reconstruct pore pressure profiles based on sonic data from LWD. Pore pressure profiles are particularly important in the creeping, extensional regime, where we plan a combined program using the sediment temperature/pressure (SETP) and temperature-dual pressure (T2P) tools to calibrate pore pressure. Emphasis will be on pore pressure changes across the proposed décollement and the BGHS. Temperature profiles are needed to constrain gas hydrate stability. Furthermore, changes in paleobottom water temperatures are a likely cause for gas hydrate dissociation leading to overpressure and sliding at the BGHS. Such bottom water changes would be reflected in anomalous temperature profiles with depth. We plan to measure subseafloor temperatures with the third generation advanced piston corer temperature (APCT-3) tool.

TLC objective 5: search for evidence of fracturing.

The hydrate-pressure valve model predicts transmission of pore pressure through fractures from hydraulic or pneumatic fracturing. We plan to constrain sediment fracturing as a function of depth at all three sites based on LWD, particularly resistivity images.

TLC objective 6: calibrate seismic data.

Further quantitative analysis of the 3-D seismic data will aim at constraining potential lateral pressure variation along the décollement and deeper layers. Results from sonic logs from LWD, tied with pressure profiles, will allow calibration of the seismic data. Furthermore, the LWD data will also provide critical shear wave calibration for long-offset seismic lines (MacMahon, 2016) and OBS site survey data (Wild, 2016) to allow for extracting information on the subsurface *S*-wave velocities using amplitude versus offset (AVO) and *P*-to-*S* converted waves.

Hikurangi subduction margin: hypotheses and scientific objectives

Drilling, downhole logging, coring, and instrumenting key targeted sites will resolve competing hypotheses and key questions regarding the generation of slow slip and the mechanics of subduction interface thrusts. The major hypotheses that will be tested are as follows:

- SSEs propagate to the trench. They are not confined to a specific (narrow) pressure or temperature range.
- Pore fluid pressure is elevated in the source region of SSEs. The elevated pore pressures are driven by mineral dehydration reactions that occur as sediments and altered igneous crust on the incoming plate are buried by subduction or by disequilibrium compaction of low-permeability subducting sediments.
- SSEs occur in regions of conditional frictional stability. A single SSE fault patch can fail by multiple slip behaviors (e.g., steady creep, episodic slow slip, and seismic slip).
- There is a continuum of duration and magnitude characteristics of SSEs and slow seismic behavior on the shallow, updip section of the subduction zone.
- Slow slip events drive fluid flow along faults and throughout the upper plate.

To test these hypotheses, Expeditions 372 and 375 collectively will undertake a coordinated strategy to accomplish three primary scientific objectives:

1. Document the in situ conditions, material properties, and composition of the subduction inputs, as well as the shallow plate boundary near the trench. These rocks comprise the protolith and reveal the initial conditions of fault rocks within the slow slip zone at greater depth. In the case of the shallow fault zone, these materials may in fact host SSEs if they propagate to the trench (Figure **F4**) (e.g., Wallace et al., 2016).
2. Characterize the stress regime, temperatures, rock physical properties, lithologies, fluid pressures, fluid geochemistry, flow pathways, and structure of the upper plate above the SSE source.
3. Install an array of borehole observatories across the upper plate that spans from the trench across the SSE source region to monitor hydrogeology, seismicity, temperature, and deformation, related to SSEs. These objectives are addressed in further detail below.

HSM objective 1: characterize the compositional, thermal, hydrogeological, frictional, geochemical, structural, and diagenetic conditions associated with the SSE rupture area.

To contribute to this goal, characterization of the incoming stratigraphy and upper oceanic basement rocks and the shallow, most active strand of the frontal thrust system is essential. We will use a combination of LWD at proposed Sites HSM-05 and HSM-18A, located in the Hikurangi Trough and frontal thrust, during Expedition 372 and coring during Expedition 375. These activities will be followed by a strategy of carefully coordinated sampling and postexpedition laboratory analyses (e.g., Screaton et al., 2009; Underwood et al., 2010). Proposed Site HSM-05A will target the entire sediment package on top of the Hikurangi Plateau. If LWD conditions allow, drilling will penetrate into the top of the basaltic lava and/or volcaniclastic sequence. Proposed Site HSM-18A will provide LWD data and material from the frontal thrust in the updip region of the plate interface early in its evolution, at low temperature and low effective stress. LWD during Expedition 372 will document continuous downhole trends in sediment properties and structure and characterize stress conditions through analysis of wellbore failures (e.g., Chang et al., 2010). After LWD, coring during Expedition 375 will provide key samples and data sets for sediment/rock physical properties, mineral composition, pore fluid composition, and downhole temperature, with a focus on hydrogeology and fault mechanical processes. In addition to proposed Site HSM-05A in the Hikurangi Trough, Expedition 375 will also drill and core a second inputs site (proposed Site HSM-08A; Saffer et al., 2017) to target the upper (<200 m), altered basaltic basement of the Tūranganui Knoll (formerly Gisborne Knolls) seamount massif. LWD and core data from all inputs sites are also critical for refined depth conversion of the existing 2-D and planned 3-D seismic data and, most importantly, to quantitatively extend knowledge of in situ conditions (stress, fault zone properties, and pore pressure) away from the boreholes over a much broader region (Bangs and Gulick, 2005; Tobin and Saffer, 2009). Overall, this objective will constrain (1) the composition and frictional properties of subduction inputs and the shallow plate interface, (2) the hydrologic and thermal conditions of the incoming plate and shallow fault, and (3) the structural character, stress conditions, and mechanical properties of the main active thrust and subduction inputs.

HSM objective 2: characterize the properties and conditions in the upper plate overlying the SSE source region.

The LWD data acquired during Expedition 372 will provide key information about microfracture and faulting patterns and will allow us to evaluate the relationship between fractured intervals and any geochemical or thermal evidence of fluid flow (e.g., Kopf et al., 2003). These data will also document wellbore failures if present (borehole breakouts and/or drilling induced tensile fractures) to determine maximum and minimum horizontal stress orientations. In combination with rock physical properties data, these data will be used to constrain stress magnitudes that may reflect variations in absolute strength of the plate boundary below (e.g., Zoback et al., 2007; Chang et al., 2010; Lin et al., 2010). Downhole temperature will constrain thermal models of the margin needed to estimate the temperature structure and its relationship to slow slip, and ultimately to estimate the loci of thermally driven dehydration reactions relative to SSE source regions (e.g., Saffer et al., 2008; Peacock, 2009). During Expedition 375, core samples collected from proposed Site HSM-01A will enable measurements of rock elastic and physical properties needed to confidently interpret observatory data and wellbore failures. Pore fluid analysis at proposed Site HSM-01A will help to evaluate the source of fluids above and surrounding the region of SSE, which may flow upward and escape through the fractured and structurally disrupted hanging wall (e.g., Kopf et al., 2003; Hensen et al., 2004; Ranero et al., 2008; Barnes et al., 2010). Core samples and downhole data from proposed Site HSM-01A will provide critical physical and elastic properties information for refined depth conversion of the existing and proposed seismic data.

For Objective 3: installation of borehole observatories spanning the SSE source region, refer to the *Expedition 375 Scientific Prospectus* (Saffer et al., 2017).

Drilling and coring strategy

Proposed drill sites

The operations and time estimates for Expedition 372 are outlined in Table **T1**. The planned operations at five of the proposed primary sites include LWD, which is discussed in **LWD/downhole measurements strategy**, below. Piston coring using the APC and half-length APC (HLAPC) systems is planned at proposed Site TLC-04B to recover the sedimentary section to 190 mbsf. Additional information is provided in **Site summaries**, and proposed alternative sites are listed in Table **T3**. Table **T4** presents a complete list of sites for the expedition with objectives for each site. A complete set of site survey data can be found in Proposal 841-Add (**http://iodp.tamu.edu/scienceops/precruise/hikurangislides/ 841-Add.pdf**) and Addendum 2 of Proposal 781-A-Full (**http://iodp.tamu.edu/scienceops/precruise/hikurangimargin/ 781A-Add2.pdf**). Below, the proposed primary sites are arranged in order of priority for the Tuaheni Landslide Complex and distance from shore for the HSM.

Tuaheni Landslide Complex

Primary extensional site: TLC-04B

Proposed Site TLC-04B (Figure **F7**) is located in the extensional, creeping part of the TLC at 720 m water depth. We plan to drill this site to 205 mbsf, penetrating the gas hydrate stability field. This site will be logged with LWD to 205 mbsf and cored to 190 mbsf (details below). This site was drilled to 80 mbsf with the MeBo system during *Sonne* Voyage SO-247 (Site GeoB20831 at TLC-04B) (Huhn, 2016), encountering deformed clayey silt landslide debris between 0 and 28 mbsf with good core recovery. Between 28 and 60 mbsf, recovery was poor, yielding disturbed very fine sandy coarse silt recovered in sections up to 1.5 m long (per 3.5 m stroke length). The cores were highly disturbed by the drilling process and mixed with seawater. From 60 to 78.8 mbsf, stiff clayey silt was sampled from within the bedded sedimentary sequence underlying the landslide complex with good core recovery. Lithology is expected to be similar down to the base of the hole at 205 mbsf, beneath the BGHS.

Primary compressional site: TLC-02C

Proposed Site TLC-02C (Figure **F8**) is located in the compressional part of the TLC at 564 m water depth. We plan to conduct LWD to 135 mbsf. The site is outside the current gas hydrate stability field. Lithology is expected to be similar to that of proposed Site TLC-04B.

Primary reference site: TLC-03B

Proposed Site TLC-03B (Figure **F9**) is a reference site outside of the TLC at 680 m water depth. We plan to conduct LWD down to 165 mbsf. The site is located within the gas hydrate stability field and outside the TLC, providing a local reference frame for a gas hydrate system that is not affected by submarine slides. It is planned to penetrate the gas hydrate stability zone. Lithology is expected to be clayey silt to fine sandy mud.

Hikurangi subduction margin

Primary upper plate site: HSM-01A

Proposed Site HSM-01A is located on the upper continental slope approximately 38 km from shore, at 994 m water depth. The site is located on seismic Profiles 05CM-04 and TAN1114-08 at the landward edge of a broad midslope sedimentary basin (Figures **F3**, **F4**). The seafloor in the basin is underlain by late Quaternary mass flow deposits and is approximately horizontal, with localized relief of <20 m in the area of the drilling site (Figures **F10**, **F11**, **AF1**). Active thrust faults of the upper plate reach the seafloor on the shelf west of the site (Mountjoy and Barnes, 2011) and on the mid-lower slope to the southeast (Barker et al., 2009; Bell et al., 2010; Pedley et al., 2010). On the basis of regional stratigraphic and seismic interpretations, the hole is expected to penetrate ~440 m of Quaternary deposits, including mass transport deposits and interlayered mud, sand, and ash. The base of this sequence is marked by an erosional unconformity underlain by seismically reflective landward-dipping strata of likely Miocene age, although Pliocene sediments may be present as well. On the basis of correlation with the Tolaga Group onshore, the sequence below the unconformity is expected to include sandy and muddy turbidites, with possible calcareous sandstone/mudstone and breccia intervals. A BSR is identified at ~570 mbsf.

Planned drilling at this site includes LWD to 650 mbsf during Expedition 372 and coring during Expedition 375. This depth will potentially place the bottom of the hole in Miocene sediments below the BSR. LWD and core data will be used to assess physical properties and rock composition in the upper plate above the SSE source region and will inform selection of the stratigraphic target for the borehole observatory installation.

Primary frontal thrust site: HSM-18A

Proposed Site HSM-18A is located on the lower continental slope near the trench, approximately 73 km from shore at 3168 m water depth (Figures **F3**, **F4**). This site is located on the fore-limb of an anticline formed by the frontal thrust (Figures **F12**, **AF5**); note that seismic Profile TAN1114-05 crosses the thrust obliquely and therefore shows an apparent dip shallower than the true dip of the frontal thrust. Planned drilling at proposed Site HSM-18A will penetrate ~450 m of the hanging wall of the frontal thrust, the frontal thrust fault, and ~250 m into the footwall. LWD to 700 mbsf is expected to encounter accreted Pleistocene trench-fill sediments comprising sand and mud turbidites, ash, and possibly mass transport deposits in both the hanging wall and footwall of the thrust.

Primary subduction inputs site: HSM-05A

Proposed Site HSM-05A is located on the floor of the Hikurangi Trough between the deformation front and Tūranganui Knoll, approximately 92 km from shore and at 3538 m water depth (Figures **F4**, **F13**). The seafloor in this location is a flat turbidite plain. The primary objective at proposed Site HSM-05A is to constrain the inputs sequence to provide insight into the lithologies and conditions expected deeper down the subduction interface within the SSE source area. The site is intentionally sited adjacent to the Tūranganui Knoll Seamount, where the turbidite trench section is relatively condensed compared to farther west, closer to the deformation front.

Proposed Site HSM-05A is expected to encounter sediments and rocks of late Quaternary to Cretaceous age (Figure **F3**, **F13**, **AF9**). Our seismic stratigraphic interpretation is based on consideration of the regional stratigraphy of the Hikurangi Plateau and Hikurangi Trough (Davy et al., 2008; Barnes et al., 2010) and age estimates of the Ruatoria avalanche and debris flow deposit (Collot et al., 2001). Beneath the seafloor, a succession of clastic trench turbidites and related sediments are interpreted to overlie the older pelagic sedimentary and volcanic sequence of the subducting Hikurangi Plateau. The upper 690 m of the section at proposed Site HSM-05A is expected to consist mainly of mud and sand turbidites, hemipelagic sediment, debris flow material, and minor ash of predominantly Pliocene–Quaternary age. The upper 450 m of the section is relatively weakly reflective compared to the lower part of this section beneath 450 mbsf and includes the ~105 m thick Ruatoria debris flow deposit. The interval between 450 and 689 mbsf at proposed Site HSM-05A is relatively strongly reflective. Moderately strong seismic reflections between 689 and 890 mbsf are interpreted to correlate with Late Cretaceous, Paleogene, and Miocene sedimentary rocks of the Hikurangi Plateau cover sequence. This interval may include nannofossil chalk, mudstone, tephra, and possible sandstone, with unconformities present. The lower sequence between 890 and 1200 mbsf is strongly reflective and may include basalts, volcaniclastic sediments, and breccia, with possible intervals of pelagic chert and/or limestone (Davy et al., 2008). Planned operations at this site comprise LWD to 1200 mbsf.

Coring strategies

Coring is planned for the extensional, creeping part of the TLC at proposed Site TLC-04B (proposed alternate Sites TLC-01D and TLC-05C; contingency plans include coring at proposed Sites TLC-02C and TLC-03B). We plan to core from the seafloor to 190 mbsf with the APC system, potentially switching to the HLAPC system and changing to the extended core barrel (XCB) system upon APC refusal. Core lengths are ~9.5 m for the APC and XCB systems and 4.7 m for the HLAPC system. Temperature profiles will be measured using the APCT-3 tool. Cores will first be investigated on the catwalk for gas hydrate occurrences using an infrared camera. Intervals for recovery of whole-round samples and for targeted pore fluid analyses will be determined based on the infrared images and on visual inspections followed by standard core processing. The latter process includes Cl^- profiles as proxies of in situ gas hydrate saturation.

We plan to conduct a T2P and SETP program to calibrate pore pressure profiles. Approximately four stations are planned at depths to be determined based on LWD and APC results. These measurements will provide calibration for using sonic velocities from LWD to obtain pore pressure profiles.

Pressure cores using the pressure core sampler (PCS) are planned at this site with depths determined from the LWD and APC results. Three pressure core barrels will be available for degassing, which takes roughly 24 h. Although we may have several attempts to successfully recover pressure cores, we are planning degassing at only three stations. Degassing aims at quantifying gas hydrate volume and obtaining samples for determining gas composition using a shipboard gas chromatograph. Gas samples will be stored for shore-based isotope analysis.

Logging-while-drilling/downhole measurements strategy

Expedition 372 will undertake LWD of Hole A at each primary site.

At the TLC, the LWD target depths are 205, 135, and 165 mbsf for proposed Sites TLC-04B, TLC-02C, and TLC-03B, respectively, including ratholes. At proposed Site TLC-04B, the maximum approved depth of penetration (205 mbsf) does not allow the full ~45 m long LWD string to cross the BGHS. The LWD string will therefore be configured so that the most relevant tools will be aligned toward the bottom of the string. The rathole at proposed Site TLC-03B is long enough for the LWD string to cross the BGHS. We will attempt to record LWD as closely to the seafloor as possible, ideally crossing the proposed décollement at proposed Site TLC-04B.

For the Hikurangi subduction sites, the target depths for LWD are 650 mbsf at proposed Site HSM-01A, 700 mbsf at proposed Site HSM-18A, and 1200 mbsf at proposed Site HSM-05A. See the *Expedition 375 Scientific Prospectus* (Saffer et al., 2017) for details of the proposed coring and borehole observatory installation activities planned at proposed Sites HSM-01A, HSM-18A, HSM-05A, and HSM-08A.

The precise measurement-while-drilling (MWD)/LWD tool string to be used during IODP Expedition 372 has not been finalized at the time of writing this *Science Prospectus*. The LWD data to be acquired, however, will include annular pressure while drilling (APWD) measurements near the drill bit for safety reasons. Other standard-suite LWD measurements may include gamma ray, resistivity at the bit and resistivity images, temperature, density, borehole caliper, neutron porosity, and sonic data.

Risks, mitigation, and contingency

A number of challenges may be associated with drilling, coring, and logging. Weather is always a potential issue because sea state and the resulting heave can have adverse effects on drilling operations. They also can significantly affect core quality and recovery. At northern Hikurangi, the mean annual wave height is 2.3 m (4.0 m at 95% and 5.1 m at 99%). There is monthly variability, with New Zealand summer months having generally lower wave conditions compared to winter months. The mean annual wind speed is 14 kt (27 kt at 95% and 32 kt at 99%). Monthly variability in wind speed largely correlates with the monthly wave variability. These conditions are considered unlikely to have any unusual effect during Expedition 372 operations. No perceived drilling operational hazards are associated with oceanographic currents in the region.

Borehole stability may be a risk during drilling and coring operations, particularly where there is no casing and sands are expected. Poor borehole conditions, such as loose unconsolidated material or collapsing holes, can cause difficulties with borehole cleaning and limit penetration. A stuck drill string is always a risk during operations and can consume expedition time while attempting to free the stuck drill string or, in the worst case, severing the stuck drill string. This could potentially result in the complete loss of the hole, lost equipment, and lost time. Routine drilling procedures to maintain hole conditions such as circulating drilling mud and wiper trips are included in the Expedition 372 operations plan. At northern Hikurangi, fine sand and silt is expected at proposed Site TLC-04B. These sediments may impact borehole stability and core recovery. The deep target sites, including proposed Sites HSM-05A, HSM-18A, and HSM-01A, are also expected to encounter unconsolidated sand-rich late Quaternary stratigraphy that could result in borehole instability, thus limiting penetration to LWD target depths. In particular, shallow sands at proposed Site HSM-05A, corresponding to the highly reflective upper ~200 m section and potentially at deeper levels, may be problematic (Figures **F13**, **AF9**, **AF10**, **AF11**). Increasing flow rates of drilling fluids to ensure borehole cleaning could potentially result in washed-out sections of unconsolidated sediment farther up these boreholes.

Fluid or gas overpressure along the Hikurangi margin has been encountered in a number of oil and gas exploration wells. All previous drilling, however, has focused on the inner margin west of the Expedition 372 drilling transect, primarily onshore. In some exploration wells from on-land and on the continental shelf 150 km south of the drilling transect, fluid-pressure trends have approached lithostatic (Darby and Funnell, 2001). Overpressure conditions are highly variable and strongly influenced by lithologies, primarily located in the Miocene and older sequences. Overpressure is particularly prevalent in Cretaceous and Paleogene sequences rich in smectite with low permeability (Darby and Funnell, 2001). The Cretaceous and Paleogene sequences extend offshore but are inferred to lie below all of the proposed upper plate sites. At the TLC sites, there is a risk of elevated gas pressure. Sites were approved by the EPSP so that potential shallow gas pockets, marked by high-amplitude events in the 3-D seismic data, are avoided. There is also a manageable risk of fluid or gas overpressure at the HSM sites, particularly below 500 mbsf in the deeper section of proposed Site HSM-01A, where landward-dipping, high-amplitude seismic reflectors are noted beneath the BSR. To mitigate the risk, Expedition 372 LWD will include APWD measurements near the drill bit. The pressure can be converted to an equivalent circulating density (ECD) that is the effective mud weight at a given depth created by both the hydrostatic pressure exerted by the mud column (including cuttings) and dynamic pressures due to the drilling process. If an appreciable amount of free gas enters the formation, the annular pressure and ECD will decrease. If a pressure decrease greater than a calculated threshold is detected, drilling will cease and circulating rate will be increased while monitoring pressure. If the normal operating pressure cannot be restored by circulating out possible gas with salt water, the hole will be killed with heavy mud and the well plugged and abandoned.

Primary Site HSM-18A and alternate Sites HSM16B, HSM-19B, HSM-21B, HSM-22B, and HSM-23B were approved by EPSP to avoid potential fluid overpressure associated with high-amplitude reflectors and possible structural closures. The same procedures will be used at these sites if overpressure is encountered during LWD.

As an operational contingency in the event of borehole abandonment at a primary site, alternate sites have been approved by the EPSP (Table **T3**).

Two proposed alternate sites have been approved for proposed Site TLC-04B: TLC-01D (Figure **F14**) and TLC-05C (Figure **F15**). Approved proposed alternate sites for proposed Site TLC-02C are TLC-06B (Figure **F16**) and TLC-07B (Figure **F17**). Proposed Site TLC-09A (Figure **F18**) has been approved as an alternate site for the proposed reference Site TLC-03B.

Three proposed alternate sites for proposed Site HSM-01A have been approved (Figures **F4**, **F10**, **F11**): HSM-21B (Figures **F10**, **F11**, **AF2**; approved to 1200 mbsf), HSM-22B (Figures **F10**, **F11**, **AF3**; approved to 1200 mbsf), and HSM-23B (Figures **F10**, **F11**, **AF4**; approved to 1300 mbsf). These sites lie within the same sedimentary basin, within 1–3 km of proposed Site HSM-01A, and are characterized by comparable seismic stratigraphy to proposed Site HSM-01A. Proposed Site HSM-21B has been identified as the priority alternate and would be the first site targeted in the event of proposed Site HSM-01A being abandoned. The target drilling depth for LWD at each of these sites is 650 mbsf.

Three proposed alternate sites for proposed Site HSM-18A have been approved (Figures **F4**, **F12**): HSM-19B (Figure **AF6**), HSM-16B (Figure **AF7**), and HSM-15A (Figure **AF8**). Proposed Site HSM-19B lies about 5 km north of proposed Site HSM-18A on the same frontal thrust (Figure **F12**). Proposed Site HSM-19B is approved to 1100 mbsf and is expected to encounter the frontal thrust and an imbricate between 887 and 964 mbsf (Figure **AF6**). Proposed Sites HSM-15A and HSM-16B lie on the hanging wall of another major thrust fault west of the deformation front. Proposed Site HSM-15A is approved to 600 mbsf and is expected to encounter the major thrust fault at 325 mbsf (Figure **AF8**). Site HSM-16B is approved to 1350 mbsf, and is expected to encounter the major thrust fault at 1055 mbsf (Figure **AF8**). All alternate sites are expected to penetrate the accreted trench turbidites and possibly some cover slope sediments. Proposed Sites HSM-16B and HSM-19B would also likely penetrate some of the subturbiditic pelagic sequence in the hanging wall of these thrust faults. Proposed site HSM-15A was identified as the priority alternate and would be targeted for LWD to the approved depth of 600 mbsf.

Two proposed alternate sites for proposed Site HSM-05A have been approved (Figures **F3**, **F13**): HSM-13B (Figure **AF10**) and HSM-14A (Figure **AF11**). Proposed Site HSM-14A lies about 1 km southwest of proposed Site HSM-05A over a very similar sequence. Proposed Site HSM-14A is approved for drilling to 1300 mbsf and is expected to encounter the top of the Hikurangi Plateau volcanics at about 987 mbsf. Proposed Site HSM-13B lies about 7 km south of proposed Site HSM-05A and has been approved for drilling to 1500 mbsf. Of the three inputs sites, proposed Site HSM-13B has the most favorable expanded lower stratigraphic pelagic sequence above the Hikurangi Plateau volcanics, which are expected at about 1245 mbsf. A collective operations strategy incorporating contingencies was developed between Expeditions 372 and 375. During Expedition 375, two possible options, depending on operational priorities (Saffer et al., 2017), are to core and possibly wireline log to 1200 mbsf at proposed Site HSM-05A or core and possibly wireline log to 1500 mbsf at proposed Site HSM-13B.

Contingencies for additional time available outside primary objectives

In the event that all of the primary coring and LWD operations are successfully completed with time to spare on the expedition, one or more of several other operations will be considered, including:

- LWD at proposed Site HSM-15A to 600 mbsf.
- APC coring at proposed Site TLC-02C to 135 mbsf.
- APC coring at proposed Site TLC-03B to 165 mbsf.

Sample and data sharing strategy

Because the objectives and original proposals for Expeditions 372 and 375 are tightly linked, sample/data requests and research plans will be shared and coordinated across both expeditions. Shipboard scientists on either expedition will be considered as part of the combined shipboard science party and will be able to request data and samples from either expedition as part of their requests.

Shipboard and shore-based researchers should refer to the IODP Sample, Data, and Obligations Policy and Implementation Guidelines (**http://www.iodp.org/top-resources/program-documents/policies-and-guidelines/114-iodp-sample-data-obligation-policy-final/file**). This document outlines the policy for distributing IODP samples and data. The document also defines the obligations that scientists incur if they receive samples and data. The Sample Allocation Committee (SAC) will work with the entire scientific party to formulate a formal expedition-specific sampling plan for shipboard and postexpedition sampling. The SAC is composed of the Co-Chief Scientists, Expedition Project Manager/Staff Scientist, and IODP Curator on shore or curatorial representative on board the ship. In the case of Expeditions 372 and 375, the four Co-Chief Scientists, two Expedition Project Managers/Staff Scientists, and IODP curatorial representatives will make up a combined SAC that will oversee the distribution of samples across both expeditions.

Every member of the science party is obligated to carry out scientific research for the expedition and publish the results. All shipboard scientists and any potential shore-based scientists are required to submit a research plan and associated sample and data request. These will be due at least 6 months before Expedition 372 (for both expeditions) using the IODP Sample and Data Request Database (**http://www.iodp.tamu.edu/sdrm**). Based on the shipboard and shore-based research plans submitted, the SAC will prepare a tentative sampling plan, which will be revised on the ship as dictated by recovery and expedition objectives. The sampling plan will be subject to modification depending upon the actual material recovered and collaborations that may evolve between scientists during the expedition. The SAC must approve modifications of the strategy during the expedition. Given the mutual objectives of both expeditions, care will be taken to maximize shared sampling to promote integration of data sets and enhance scientific collaboration among members of both scientific parties. All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the expedition objectives.

Shipboard sampling will include samples taken for shipboard analyses and samples needed for personal postexpedition research. We expect a large number of shipboard and personal whole-round samples to be taken for geochemical, microbiological, and petrophysical measurements. If some critical intervals are recovered, there may be considerable demand for samples from a limited amount of cored material. These intervals may require special handling or reduced sample size and frequency. The SAC may require an additional formal sampling plan to be developed for critical intervals. All archive halves will be designated as permanent archives and will not be sampled.

The cores from both Expeditions 372 and 375 will be delivered to the IODP Gulf Coast Repository in College Station, Texas (USA), for permanent storage. All Expedition 372 and 375 data and samples will be protected by a 1 y moratorium period that will start at the end Expedition 375. During this moratorium, all data and samples will be available only to the expedition shipboard scientists and approved shore-based participants.

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Table T1. Primary sites and operations plan for Expedition 372. LWD = logging while drilling, APC = advanced piston corer, HLAPC = half-length APC, APCT-3 = advanced piston corer temperature tool, T2P = temperature-dual pressure tool, SETP = sediment temperature/pressure tool.

Proposed site	Location (latitude, longitude)	Seafloor depth (mbrf)	Operations	Transit (days)	Drilling, coring (days)	Wireline log/LWD (days)
Fremantle, Australia			**Begin expedition** **5.0**	**Port call days**		
			Transit ~3447 nmi from Fremantle to Site TLC-04B @ 10.5 kt	13.8		
TLC-04B Depth approved by EPSP to 205 mbsf	38°49.7720'S 178°28.5553'E	731	Hole A: LWD to 205 mbsf Hole B: APC/HLAPC coring with APCT-3 temperature measurements to 190 mbsf **Subtotal days on-site: 2.8**		1.4	1.4
			Transit ~22 nmi to Site HSM-18A @ 10.5 kt	0.1		
HSM-18A Depth approved by EPSP to 800 mbsf	38°52.3145'S 178°56.3957'E	3179	Hole A: LWD to 700 mbsf **Subtotal days on-site: 2.9**			2.9
			Transit ~18 nmi to Site HSM-01A @ 10.5 kt	0.1		
HSM-01A Depth approved by EPSP to 1180 mbsf	38°43.6370'S 178°36.8540'E	1005	Hole A: LWD to 650 mbsf **Subtotal days on-site: 2.1**			2.1
			Transit ~9 nmi to TLC-04B Coring @ 10.5 kt	0.1		
TLC-04B Depth approved by EPSP to 205 mbsf	38°49.7720'S 178°28.5553'E	731	Hole C: Pressure coring & T2P/SETP pressure measurements **Subtotal days on-site: 2.3**		2.3	
			Transit ~3 nmi to Site TLC-02C LWD @ 10.5 kt	0.1		
TLC-02C Depth approved by EPSP to 135 mbsf	38°47.5549'S 178°26.8485'E	575	Hole A: LWD to 135 mbsf **Subtotal days on-site: 1.2**			1.2
			Transit ~3 nmi Site TLC-03B LWD @ 10.5 kt	0.1		
TLC-03B Depth approved by EPSP to 165 mbsf	38°49.6015'S 178°30.1838'E	691	Hole A: LWD to 165 mbsf **Subtotal days on-site: 1.3**			1.3
			Transit ~31 nmi to Site HSM-5A @ 10.5 kt	0.2		
HSM-05A Depth approved by EPSP to 1400 mbsf	38°58.1640'S 179°7.9350'E	3549	Hole A: LWD to 1200 mbsf **Subtotal days on-site: 5.7**			5.7
			Transit ~316 nmi to Wellington @ 10.5 kt	1.3		
Wellington, NZ			**End expedition**	**15.7**	**3.8**	**14.5**

Port call:	**5.0**	**Total operating days:**	**34.0**
Subtotal on-site:	**18.3**	**Total expedition:**	**39.0**

Table T2. Summary of core description from MeBo drilling at Site GeoB20831 (proposed Site TLC-04B) (after Huhn, 2016).

Depth (mbsf)	Recovery	Core description
0–28	Good recovery	Deformed clayey silt landslide debris.
28–60	Poor recovery	Disturbed very fine sandy coarse silt recovered in sections up to 1.5 m long (per 3.5 m stroke length). Highly disturbed by drilling process and mixed with seawater.
60–78.8	Good recovery	Stiff clayey silt. Intact, bedded sedimentary sequence underlying landslide complex.

Table T3. Alternate sites and operations plan for Expedition 372. LWD = logging while drilling, APC = advanced piston corer, HLAPC = half-length APC, APCT-3 = advanced piston corer temperature tool, T2P = temperature-dual pressure tool, SETP = sediment temperature pressure tool.

Proposed site	Location (latitude, longitude)	Seafloor depth (mbrf)	Operations	Drilling, coring (days)	LWD (days)	Total time on site
TLC-01D Depth approved by EPSP to 155 mbsf	38°49.1740'S 178°27.847'E	680	Hole A: LWD to ~155 mbsf Hole B: APC/HLAPC (with APCT-3 temperature measurements) to ~155 mbsf Hole C: Pressure Coring (with T2P/SETP pressure measurements) to ~155 mbsf	 0.9 2.0	1.1	4.0
TLC-02C Depth approved by EPSP to 135 mbsf	38°47.5549'S 178°26.8485'E	575	Hole A: APC to ~135 mbsf	0.7		0.7
TLC-05C 155 mbsf pending correction to EPSP minutes	38°49.4582'S 178°27.7824'E	688	Hole A: LWD to ~135 mbsf Hole B: APC/HLAPC (with APCT-3 temperature measurements) to ~135 mbsf Hole C: Pressure Coring (with T2P/SETP pressure measurements) to ~135 mbsf	1.0 0.8 1.9	1.0	4.8
TLC-06B Depth approved by EPSP to 135 mbsf	38°47.5874'S 178°26.9390'E	579	Hole A: LWD to ~135 mbsf		1.1	1.1
TLC-07B Depth approved by EPSP to 155 mbsf	38°46.506'S 178°27.135'E	559	Hole A: LWD to ~155 mbsf		1.1	1.1
TLC-09A Depth approved by EPSP to 195 mbsf	38°51.0616'S 178°27.9579'E	674	Hole A: LWD to ~195 mbsf		1.2	1.2
HSM-13B Depth approved by EPSP to 1500 mbsf	39°2.3283'S 179°7.6835'E	3519	Hole A: LWD to ~1500 mbsf		6.6	6.6
HSM-14A Depth approved by EPSP to 1300 mbsf	38°58.4952'S 179°7.2925'E	3542	Hole A: LWD to ~1300 mbsf		5.5	5.5
HSM-15A Depth approved by EPSP to 600 mbsf	38°51.5367'S 178°53.7603'E	2735	Hole A: LWD to ~600 mbsf		2.1	2.1
HSM-16B Depth approved by EPSP to 1350 mbsf	38°54.8043'S 178°54.4105'E	2443	Hole A: LWD to ~1350 mbsf		5.6	5.6
HSM-19B Depth approved by EPSP to 1100 mbsf	38°50.1660'S 178°56.6342'E	3035	Hole A: LWD to ~1100 mbsf		4.3	4.3
HSM-21B Depth approved by EPSP to 1200 mbsf	38°43.2033'S 178°37.1140'E	1022	Hole A: LWD to ~650 mbsf		2.0	2.0
HSM-22B Depth approved by EPSP to 1200 mbsf	38°43.0937'S 178°38.5527'E	1052	Hole A: LWD to ~650 mbsf		2.0	2.0
HSM-23B Depth approved by EPSP to 1300 mbsf	38°43.0230'S 178°38.9733'E	1056	Hole A: LWD to ~650 mbsf		2.0	2.0

Table T4. Primary and alternate sites proposed for Expedition 372

Site	Position (latitude, longitude)	Water depth (m)	Approved drilling penetration (m) Sediment	Basement	Total	Objective
TLC-04B	38.830°S, 178.476°E	720	205	0	205	Determine presence of methane hydrates within landslide debris. Characterize distribution of hydrate. Determine overpressure at base of landslide debris and below hydrate stability. Collect pressure cores for shore-based studies of interstitial distribution of hydrates and mechanical properties. Primary site.
TLC-02C	38.793°S, 178.448°E	564	135	0	135	Determine if gas hydrate or free gas present. Determine potential overpressure. Primary site.
TLC-03B	38.827°S, 178.503°E	680	165	0	165	Determine properties of gas hydrate bearing sediments outside slide mass. Primary site.
TLC-01D	38.820°S, 178.464°E	669	155	0	155	Determine presence of methane hydrates within landslide debris. Characterize distribution of hydrate. Determine overpressure at base of landslide debris and below hydrate stability. Collect pressure cores for shore-based studies of interstitial distribution of hydrates and mechanical properties. Alternate site to TLC-04B.
TLC-05C	38.824°S, 178.463°E	677	155	0	155	Determine presence of methane hydrates within landslide debris. Characterize distribution of hydrate. Determine overpressure at base of landslide debris and below hydrate stability. Collect pressure cores for shore-based studies of interstitial distribution of hydrates and mechanical properties. Alternate site to TLC-04B.
TLC-06B	38.793°S, 178.449°E	568	135	0	135	Determine if gas hydrate or free gas present. Determine potential overpressure. Alternate site to TLC-02C.
TLC-07B	38.775°S, 178.452°E	548	155	0	155	Determine if gas hydrate or free gas present. Determine potential overpressure. Alternate site to TLC-02C.
TLC-09A	38.851°S, 178.466°E	663	195	0	195	Determine properties of gas hydrate bearing sediments outside slide mass. Alternate site to TLC-03B.
HSM-01A	38.727°S, 178.614°E	994	1180	0	1180	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Case and install SSE observatory hole (tilt, seismology, pore pressure). Primary site
HSM-05A	38.969°S, 179.132°E	3538	1400	0	1400	Coring and logging to characterize the age, lithology, physical and thermal properties of the sedimentary sequence and underlying volcanic basement on subducting plate. Primary site.
HSM-13B	39.039°S, 179.128°E	3508	1500	0	1500	Coring and logging to characterize the age, lithology, physical and thermal properties of the sedimentary sequence and underlying volcanic basement on subducting plate. Alternate site to HSM-05A.
HSM-14A	38.975°S, 179.122°E	3531	1300	0	1300	Coring and logging to characterize the age, lithology, physical and thermal properties of the sedimentary sequence and underlying volcanic basement on subducting plate. Alternate site to HSM-05A.
HSM-15A	38.859°S, 178.896°E	2724	600	0	600	Coring and logging to establish shallow fault zone properties, composition, and conditions. Case and install CORK for hydrologic, geochemical, and deformation monitoring throughout SSE cycle. Alternate site to HSM-18A.
HSM-16B	38.913°S, 178.907°E	2432	1350	0	1350	Coring and logging to establish shallow fault zone properties, composition, and conditions. Case and install CORK for hydrologic, geochemical, and deformation monitoring throughout SSE cycle. Alternate site to HSM-18A.
HSM-18A	38.872°S, 178.940°E	3168	800	0	800	Coring and logging to establish shallow fault zone properties, composition, and conditions. Case and install CORK for hydrologic, geochemical, and deformation monitoring throughout SSE cycle. Primary site.
HSM-19B	38.836°S, 178.944°E	3024	1100	0	1100	Coring and logging to establish shallow fault zone properties, composition, and conditions. Case and install CORK for hydrologic, geochemical, and deformation monitoring throughout SSE cycle. Alternate site to HSM-18A.
HSM-21B	38.720°S, 178.619°E	1011	1200	0	1200	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Case and install SSE observatory hole (tilt, seismology, pore pressure). Alternate site to HSM-01A.
HSM-22B	38.718°S, 178.643°E	1041	1200	0	1200	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Case and install SSE observatory hole (tilt, seismology, pore pressure). Alternate site to HSM-01A.
HSM-23B	38.717°S, 178.649°E	1045	1300	0	1300	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Case and install SSE observatory hole (tilt, seismology, pore pressure). Alternate site to HSM-01A.

Figure F1. A, B. Location maps. C. Seismic profile extracted from 3-D cube connecting approximate locations of proposed Sites TLC-01D and TLC-02C. Yellow arrows = possible fault planes (reverse faults to the northwest, normal faults to the southeast), red arrows = interpreted décollement. D. 2-D seismic Section TAN1114 through the 3-D cube. Lower frequencies resulted in greater penetration but lower resolution compared to 3-D data. Sites are projected into the line. Solid line = base of TLC slide mass, dashed line = earlier interpretation of base of creeping (after Mountjoy et al., 2014b). E. Cross-line through proposed Site TLC-03B.

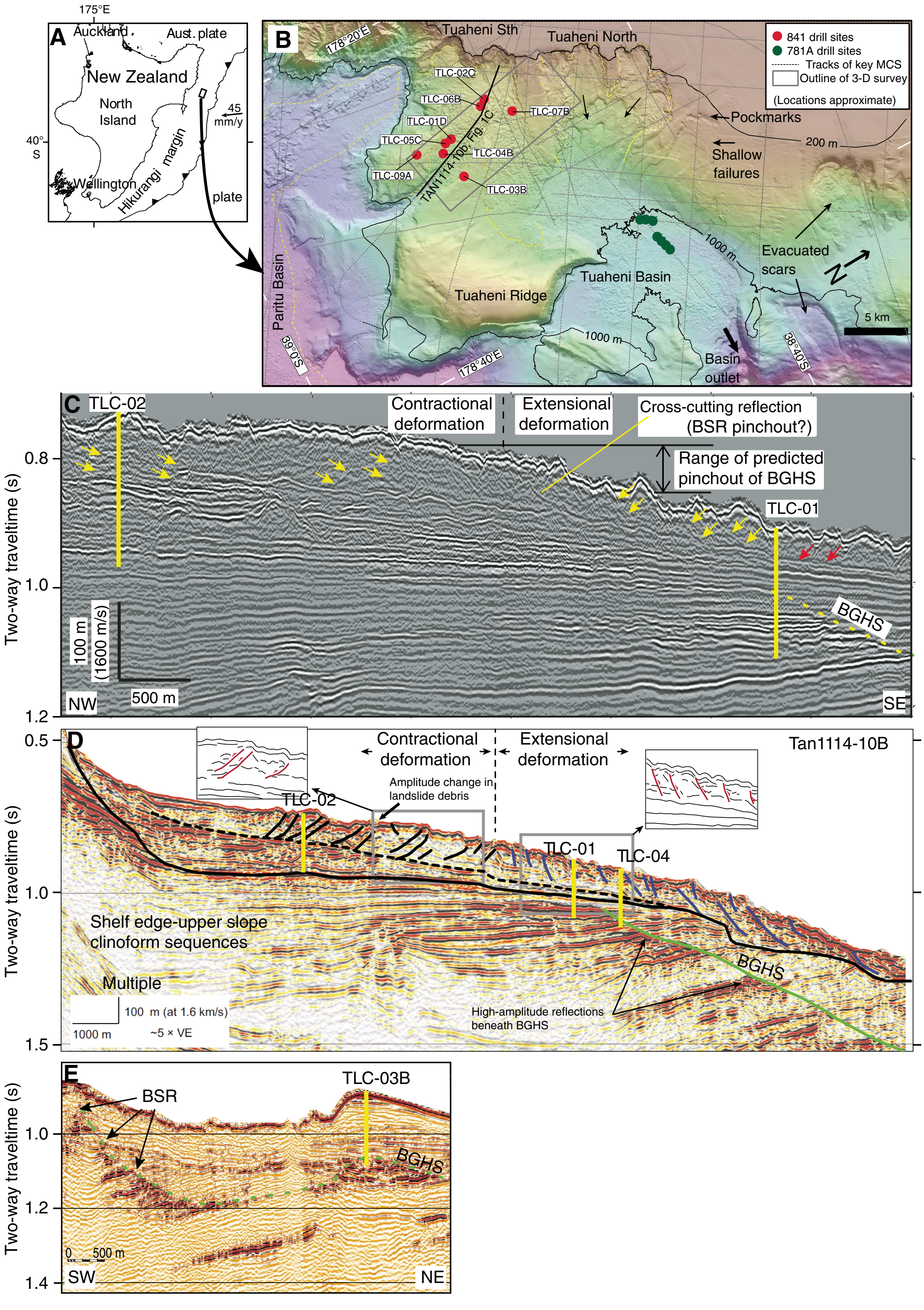


Figure F2. Tectonic setting (upper left inset) and location of slip on the interface in the January/February (green contours) and the March/April (orange contours) 2010 SSEs (Wallace and Beavan, 2010) and the reflective properties of the subduction interface (Bell et al., 2010) at northern Hikurangi. Black dashed line shows the location of the drilling transect (see Figure F2); pink ellipses are the planned drill sites. Blue dots are locations of triggered seismicity during the January/February 2010 SSE. Red stars are locations of two tsunamigenic subduction interface earthquakes (Mw 6.9–7.1) in March and May of 1947. Lower left inset shows the east component of the position time series for a cGPS site near Gisborne to demonstrate the repeatability of SSEs since they were first observed in 2002.

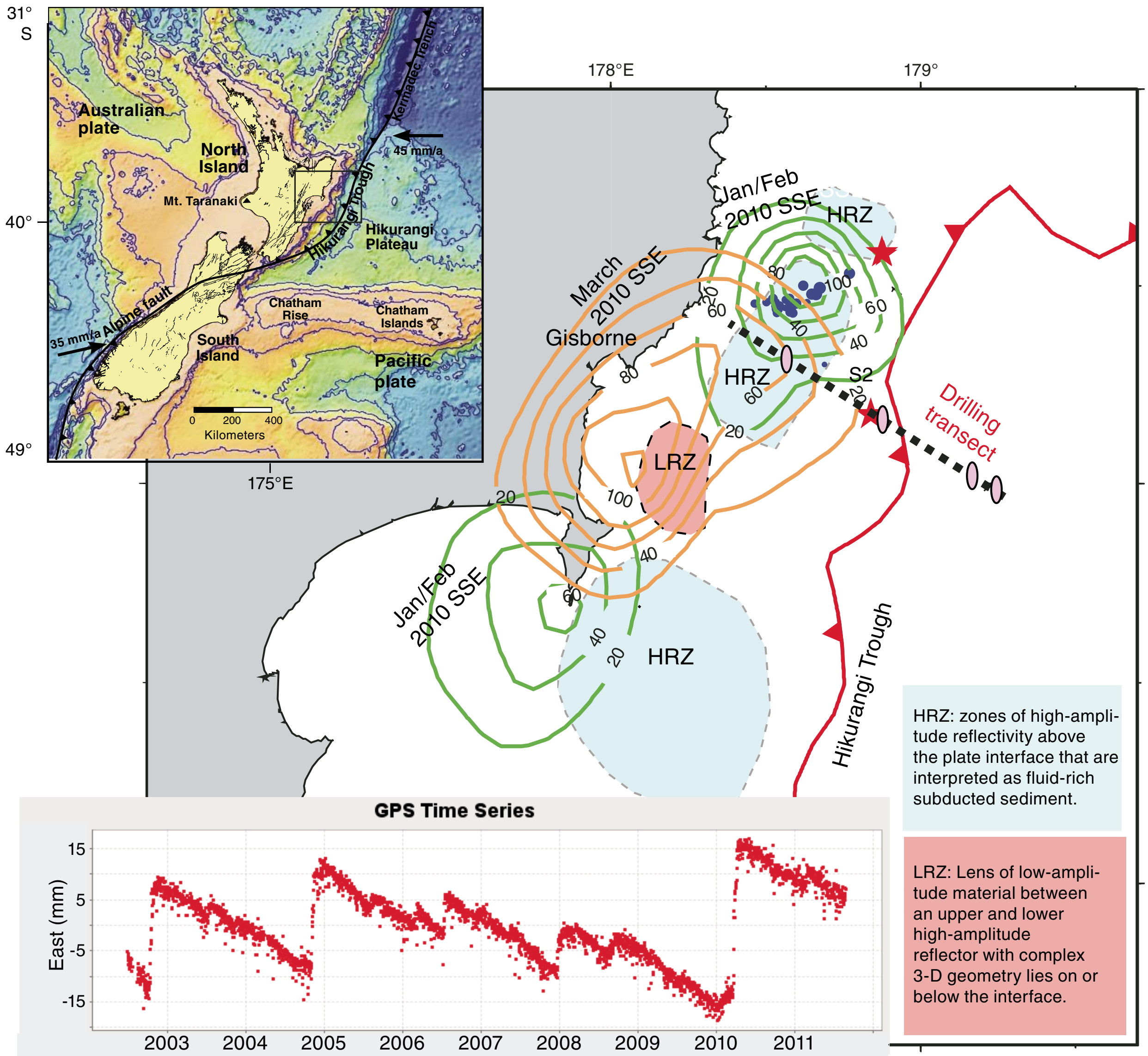


Figure F3. A. Interpretation of regional depth-converted seismic Profile 05CM-04, showing major faults, annotated seismic reflections, and proposed primary Sites HSM-01A, HSM-18A (projected 890 m), and HSM-05A. B. Enlarged section of the frontal accretionary wedge and subducting Hikurangi Plateau. HKB = Hikurangi Basement Sequence.

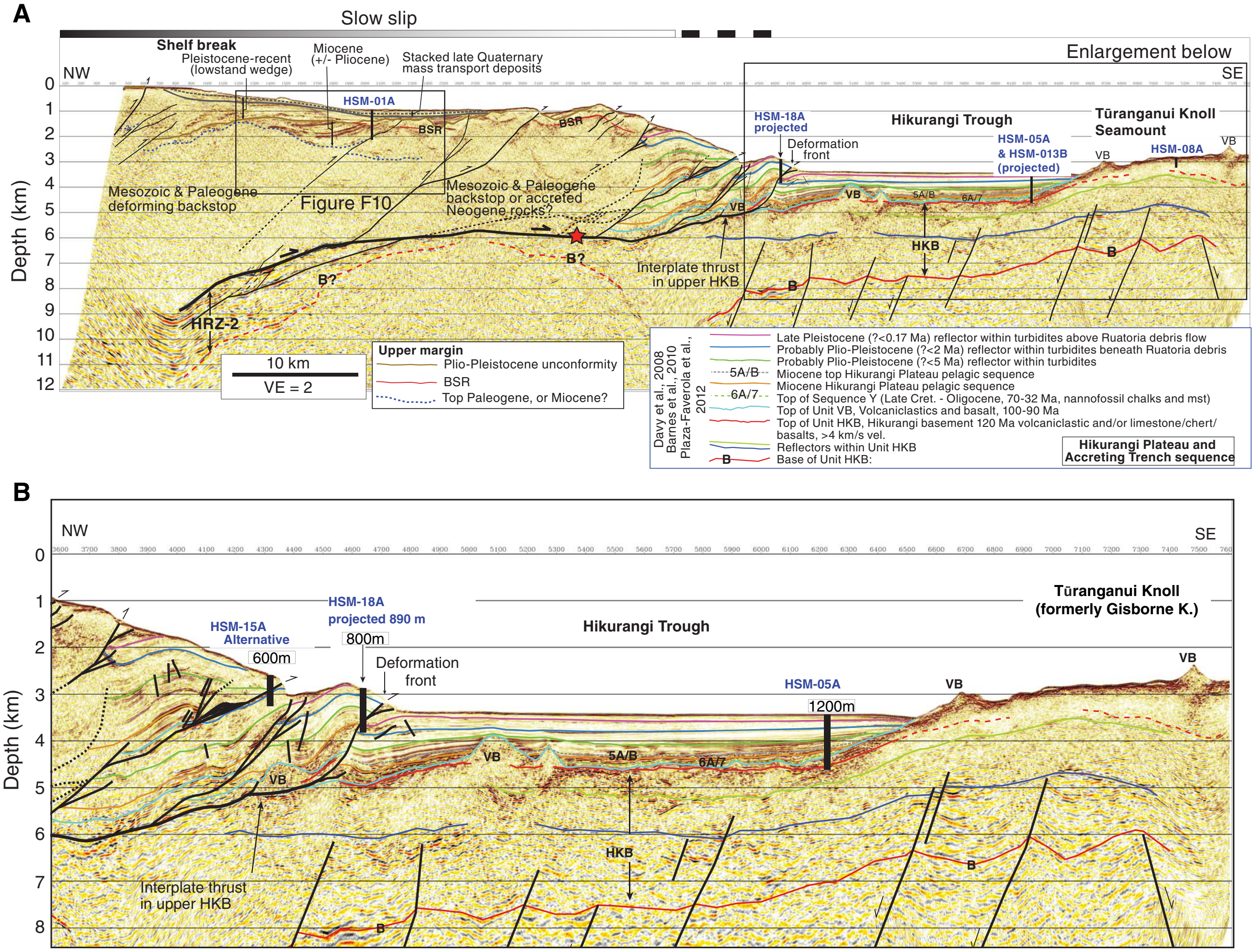


Figure F4. A. Regional map showing the extent of the recent offshore SSE identified by Wallace et al. (2016) using offshore geodetic data. Colored symbols = onshore cGPS stations, small circles = microearthquakes, fine red lines = major faults from Pedley et al. (2010) and Mountjoy and Barnes (2011). (Continued on next page.)

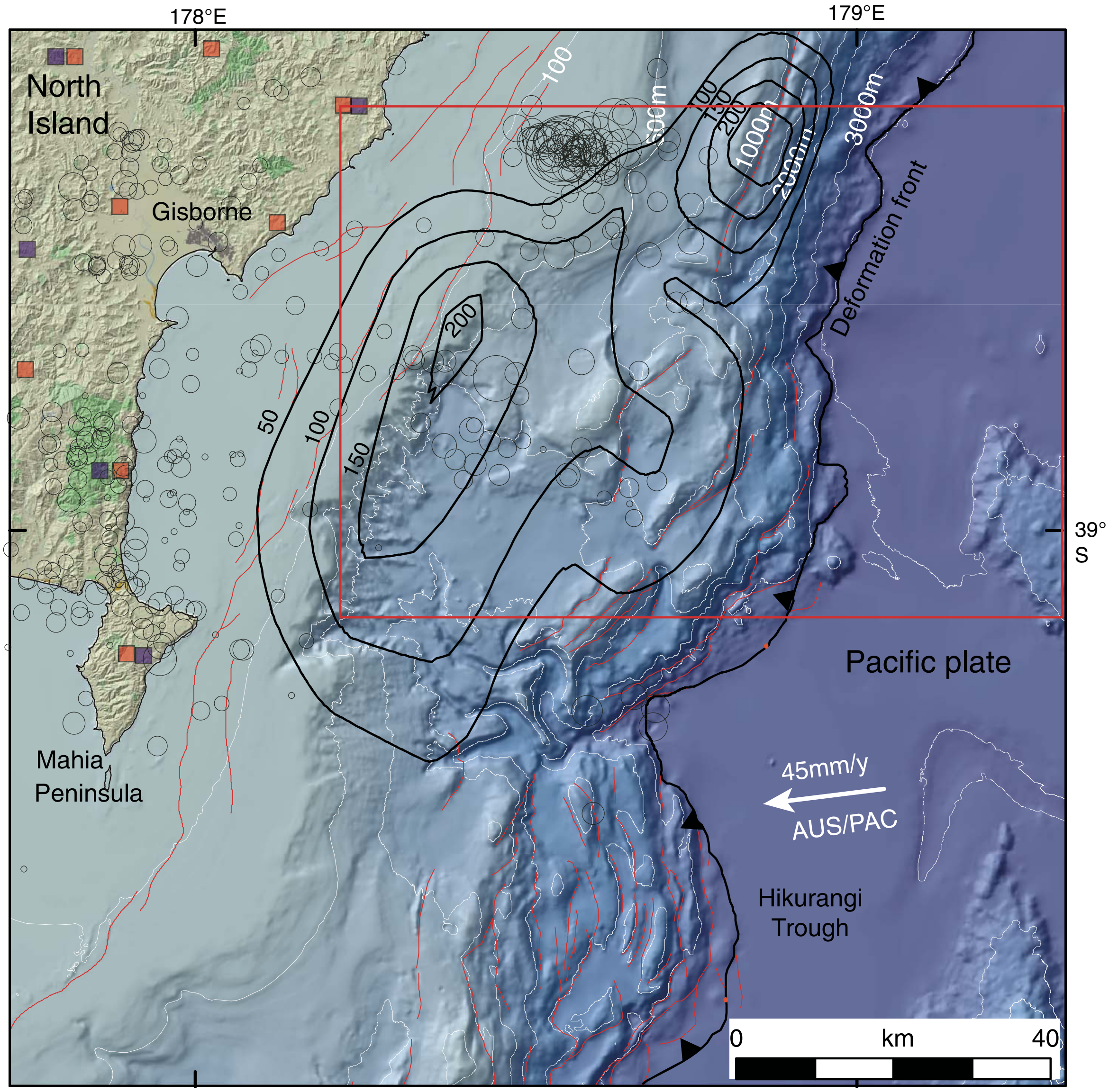


Figure F4 (continued). B. Enlarged map showing regional seismic sections. Black lines = high-fold, deep penetration data with drilling transect, center line = Profile 05CM-04, white lines = low-fold seismic data including site Surveys TAN1114 and TAN1213. Yellow circles = three primary drilling sites, red circles = alternates.

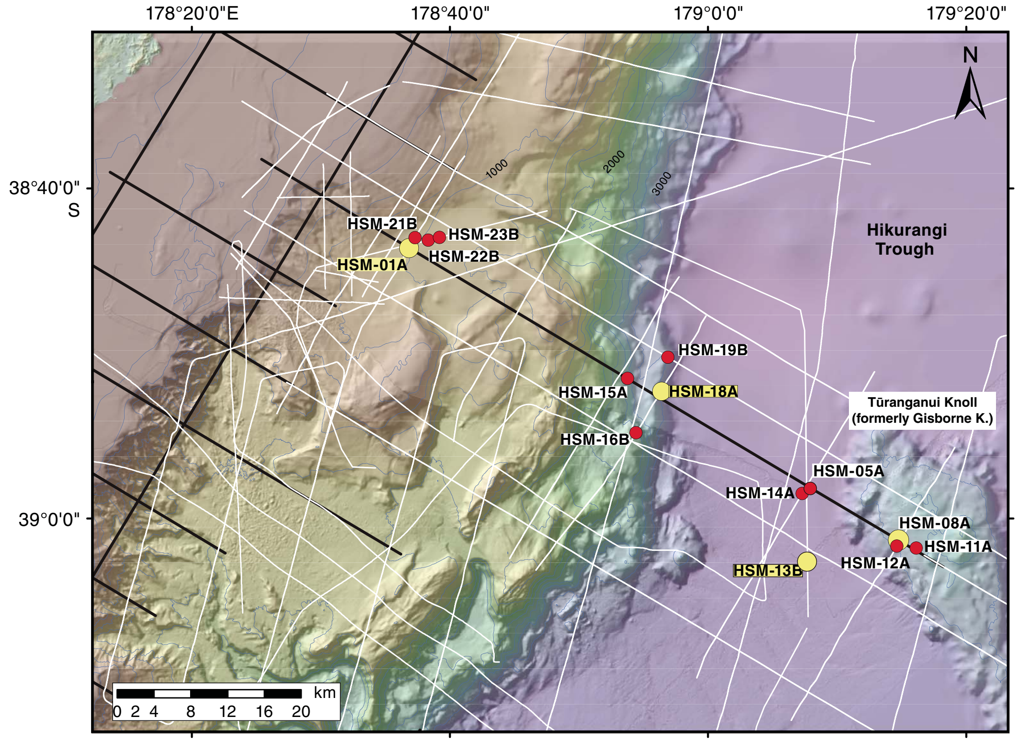


Figure F5. Locations of drill sites in the TLC with grid of in-lines and cross-lines of the 3-D seismic cube and tracks of key 2-D seismic lines.

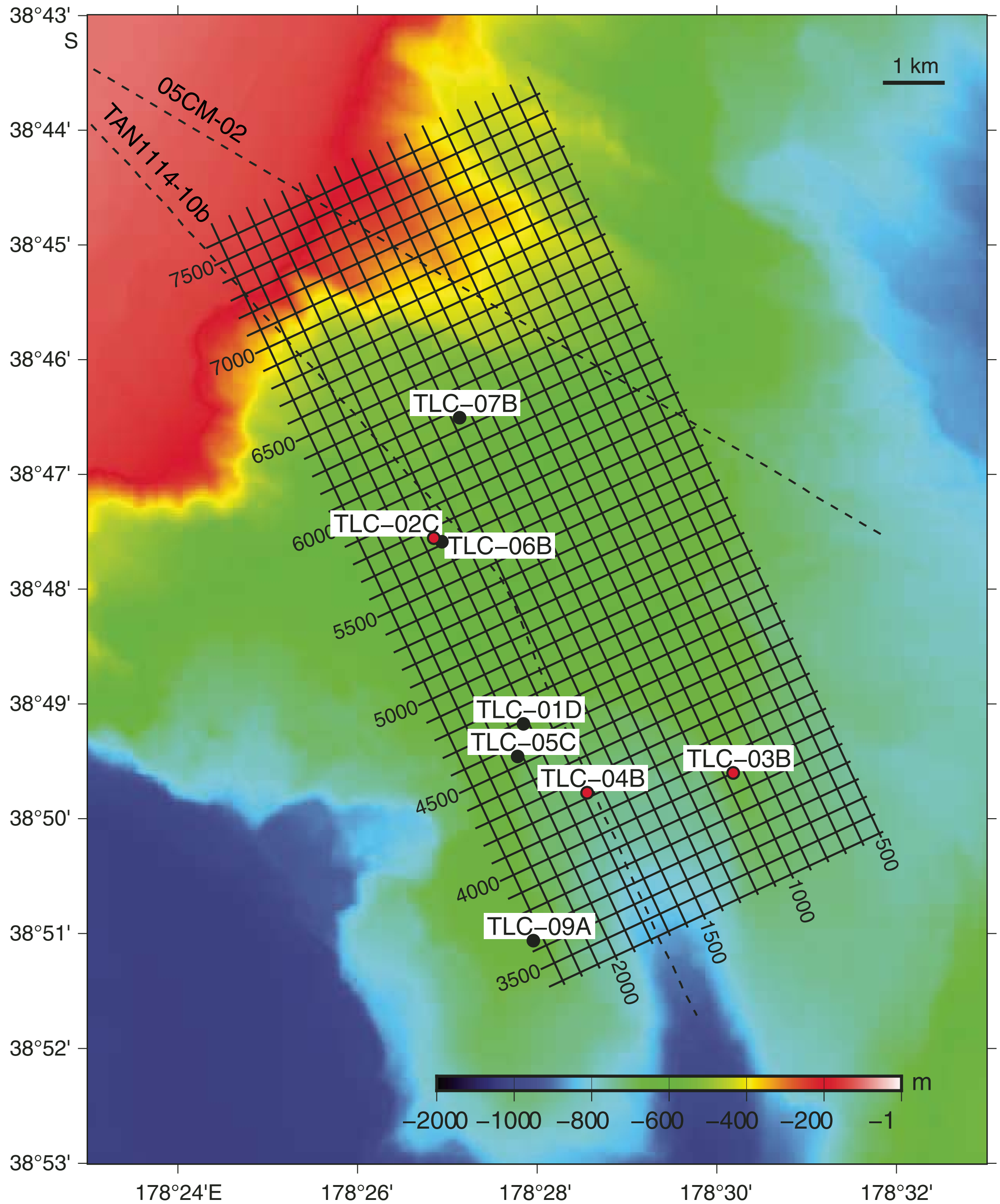


Figure F6. Hypotheses for gas hydrate–related creeping and predicted resulting sediment microstructure (after Mountjoy et al., 2014b).

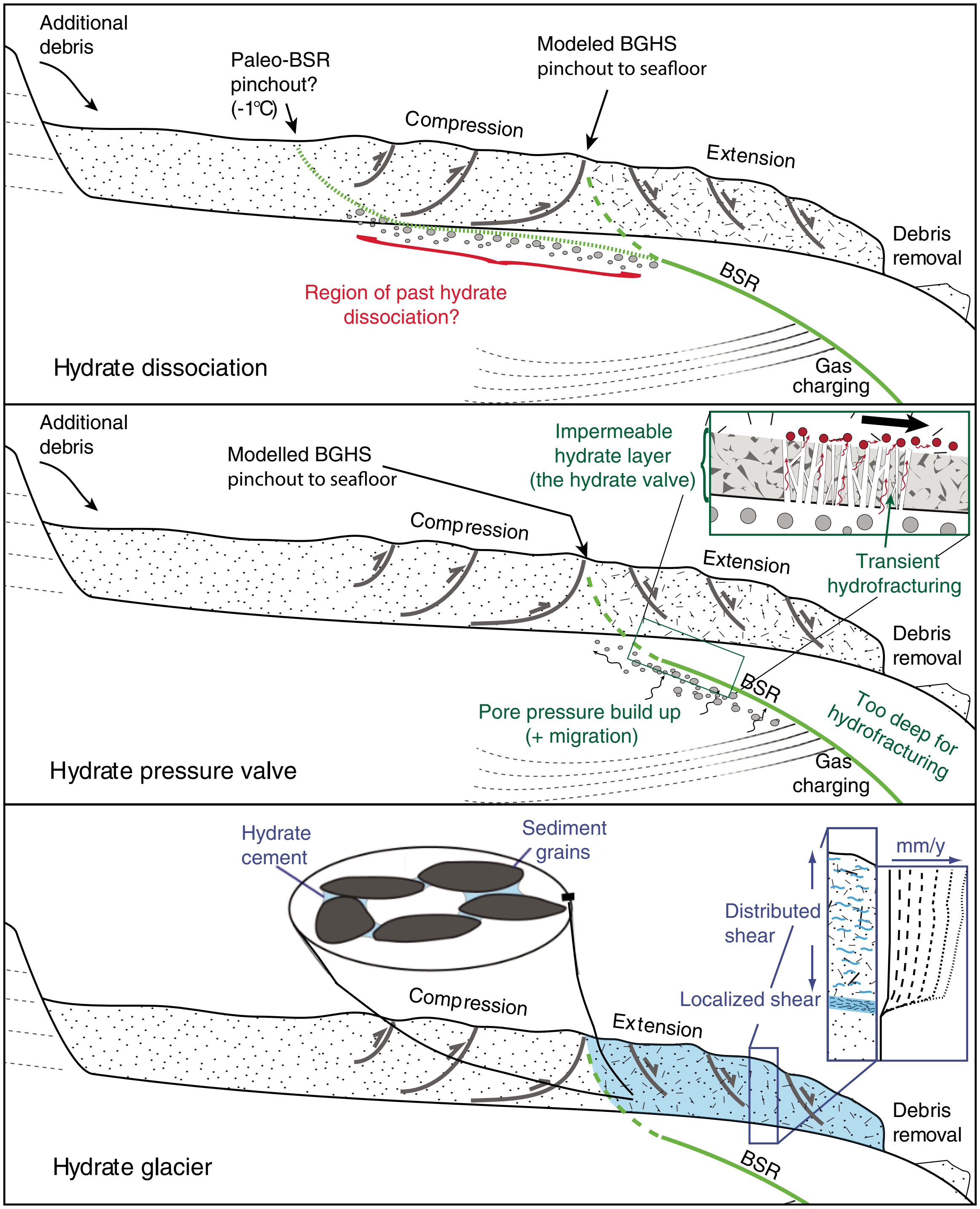


Figure F7. In-line across proposed primary Site TLC-04B with interpretation.

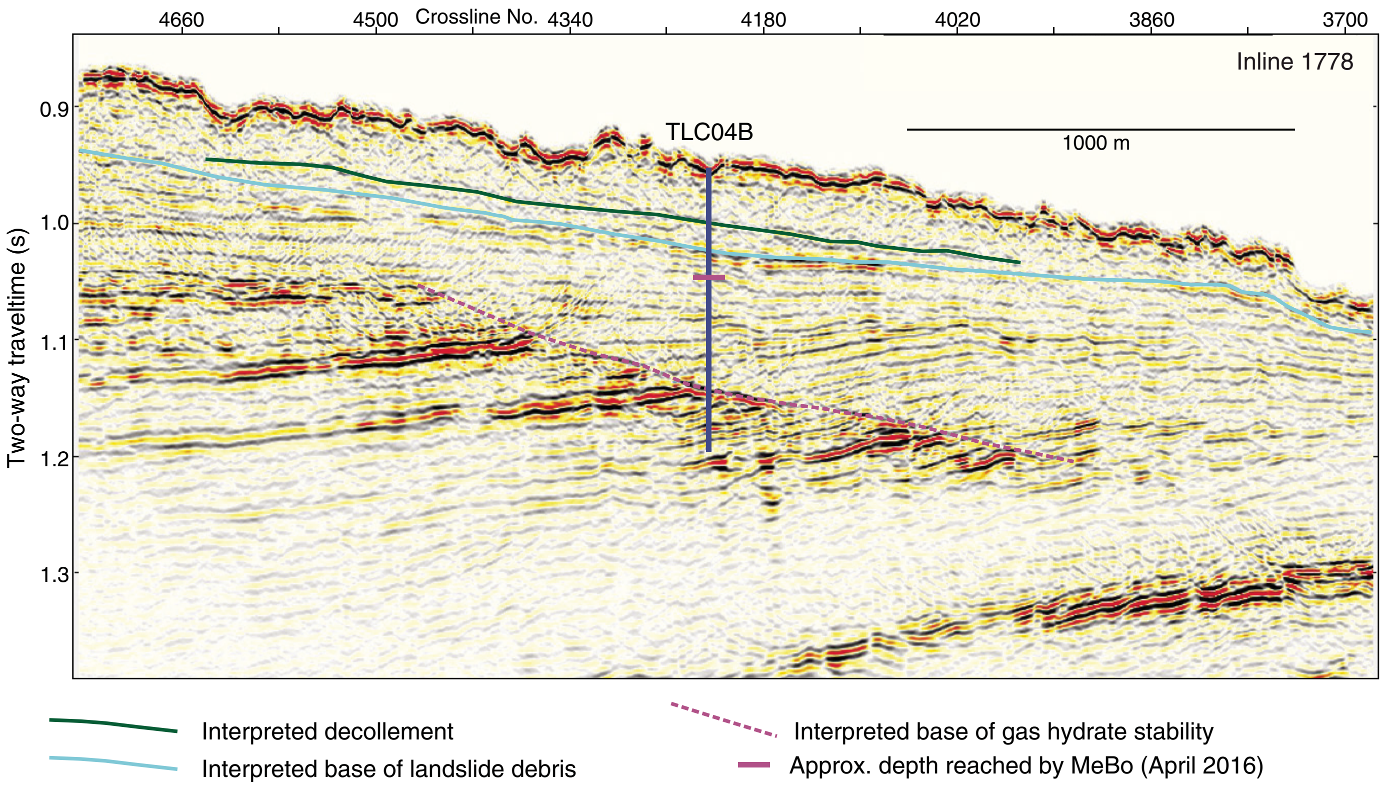


Figure F8. In-line across proposed primary Site TLC-02C with interpretation.

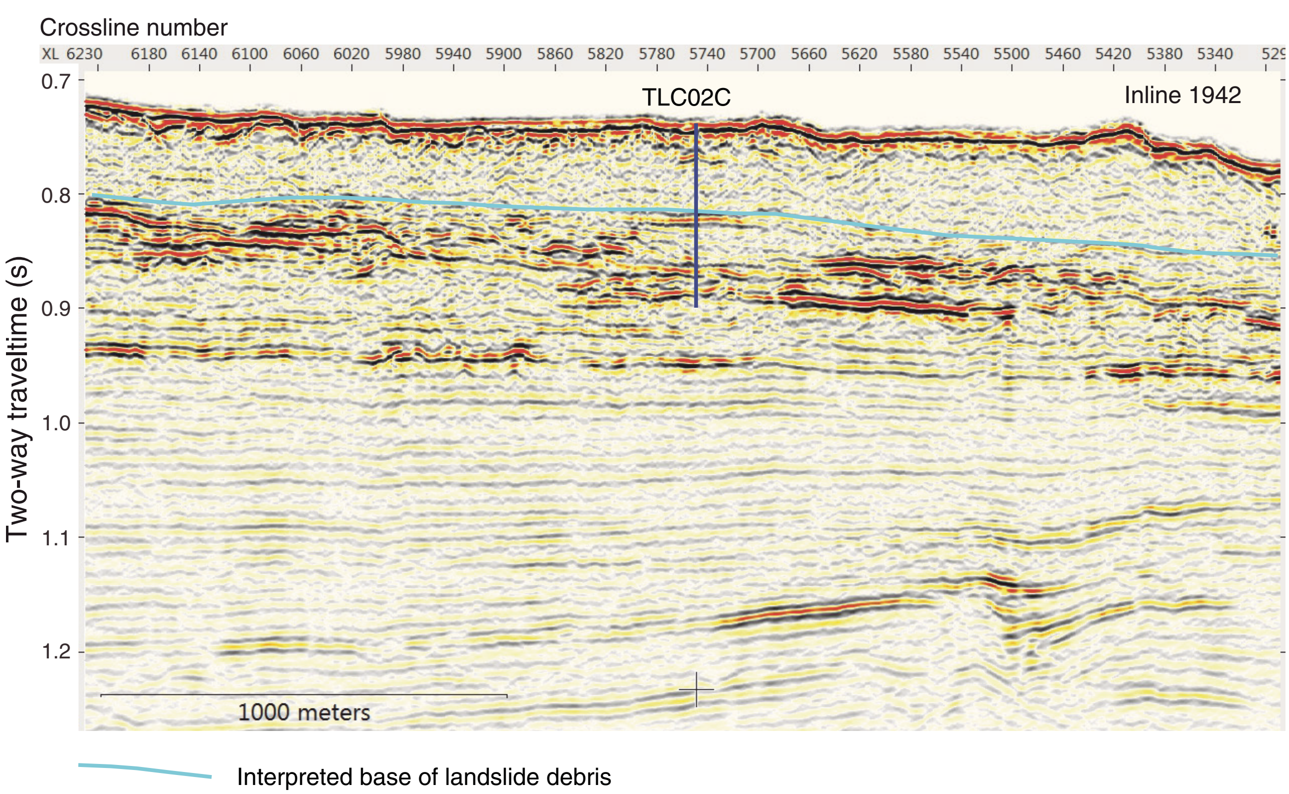


Figure F9. In-line across proposed primary Site TLC-03B with interpretation.

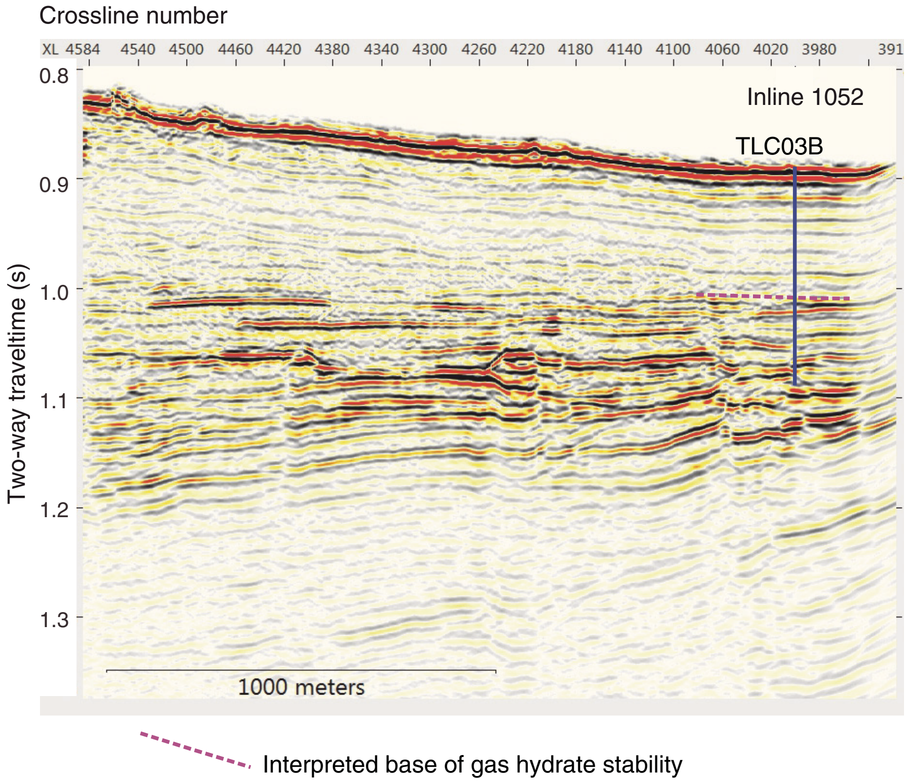


Figure F10. A. Map of proposed upper plate primary site HSM-01A and alternate sites (red dots). B. Seismic Profile 05CM-04 showing regional setting of site.

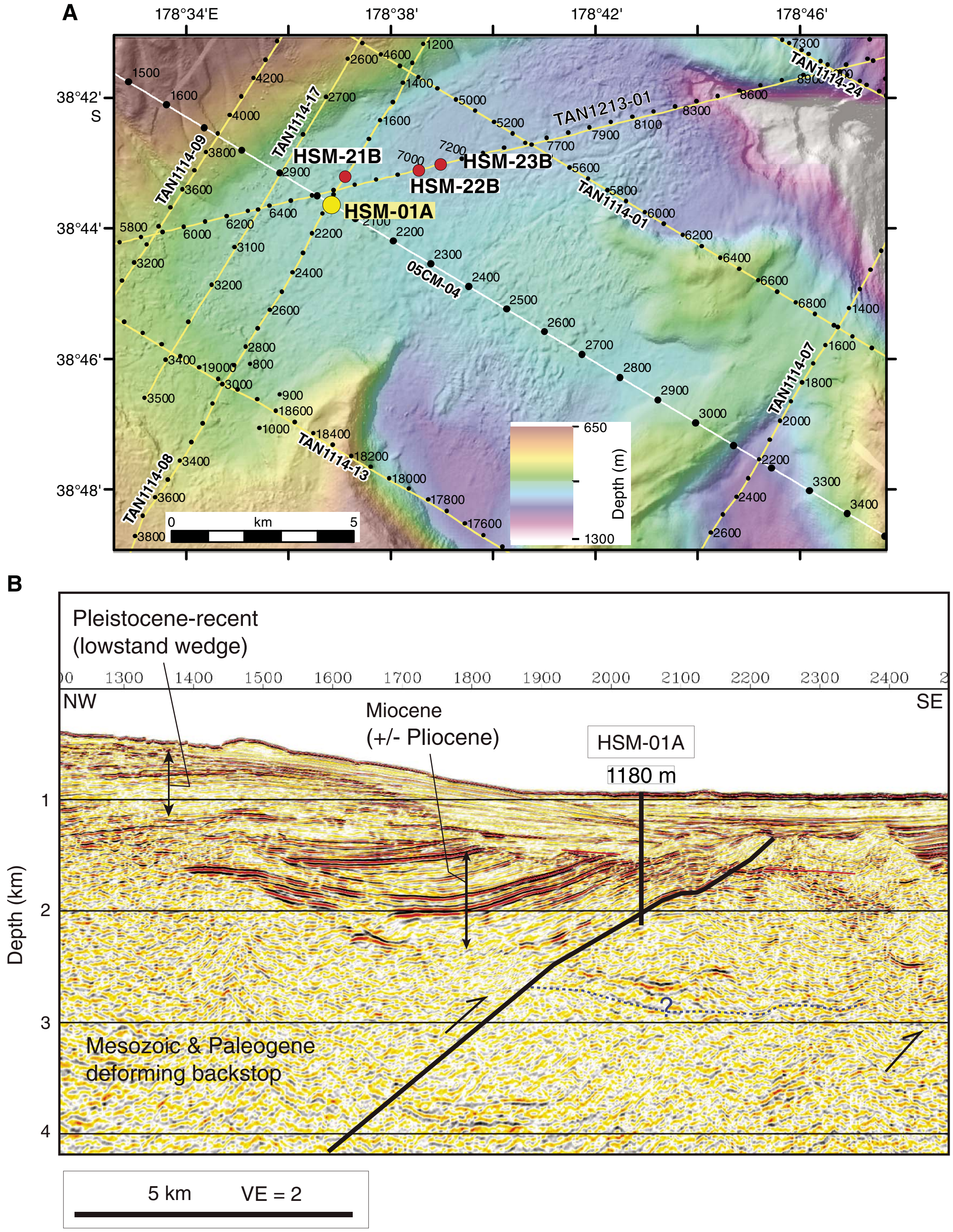
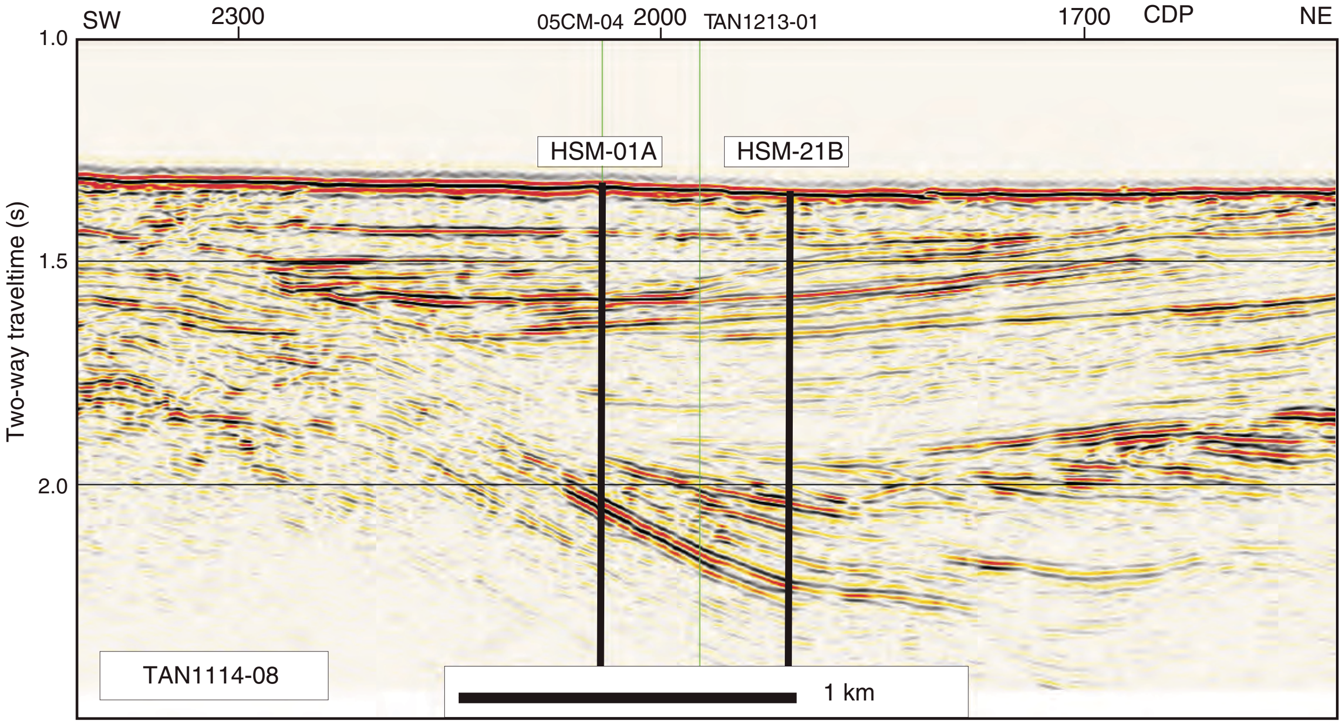


Figure F11. Seismic Profiles Tan1114-08 (top) and TAN1213-01 (bottom) illustrating locations of proposed primary Site HSM-01A, and proposed alternate Sites HSM-21B, HMS-22B, and HSM-23B.



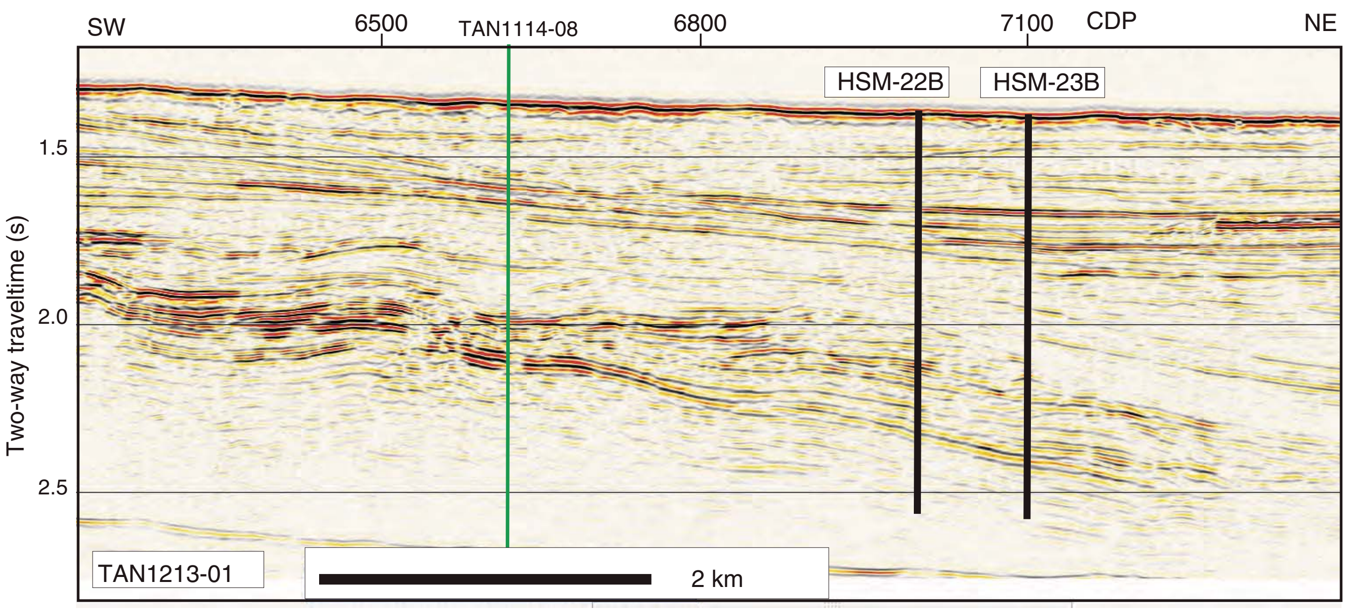


Figure F12. (A) Map and (B–D) regional seismic profiles illustrating (B) proposed frontal thrust primary Site HSM-18A and proposed alternate Sites HSM-15A (see Figure F3B) and HSM-16B, (C) HSM-19B, and (D) HSM-15A. (Continued on next page.)

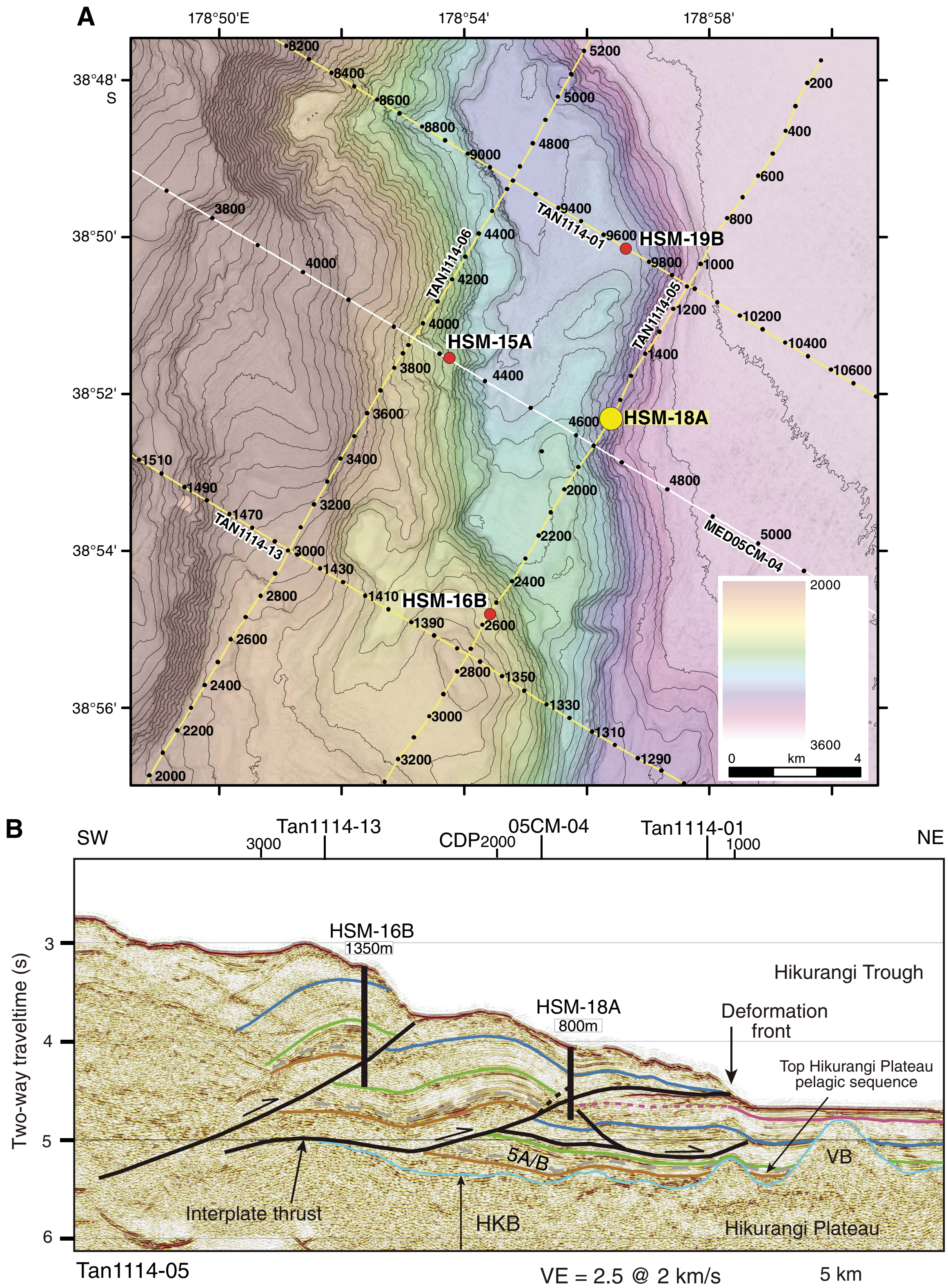
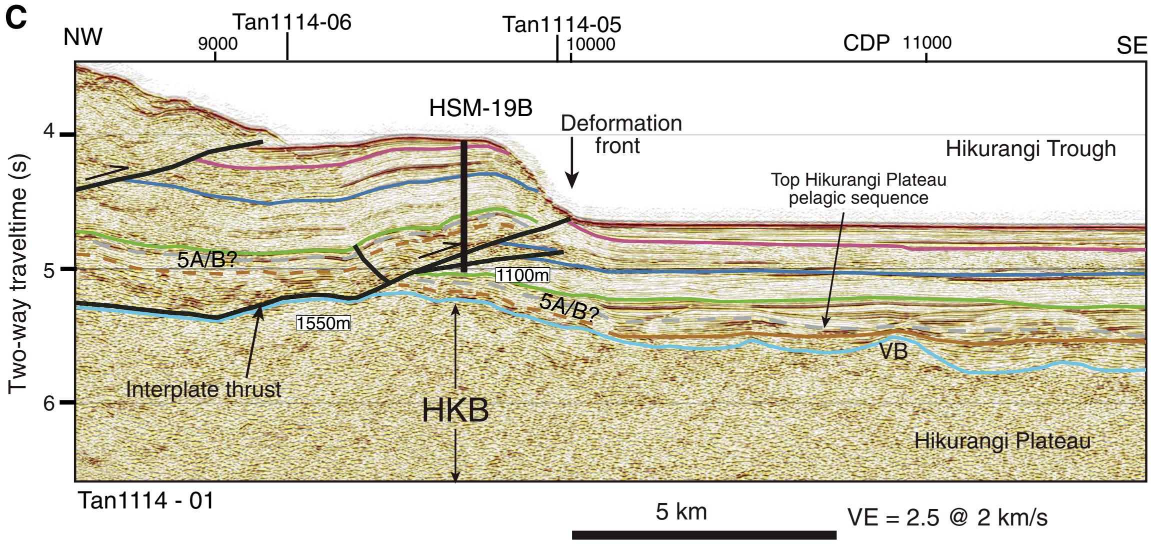


Figure F12 (continued).



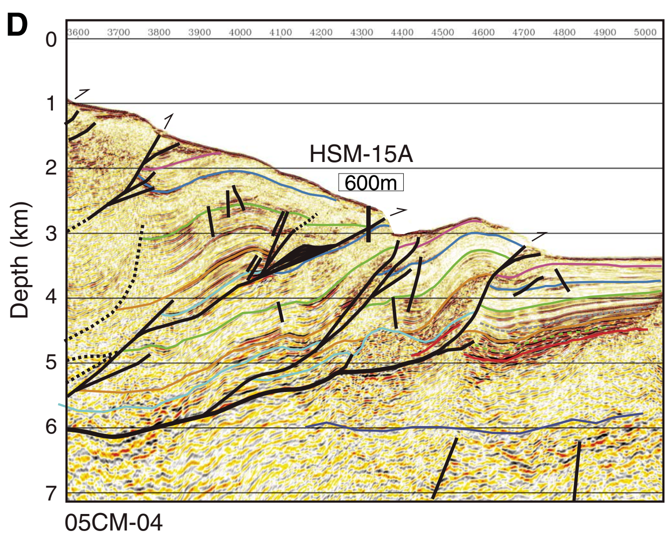
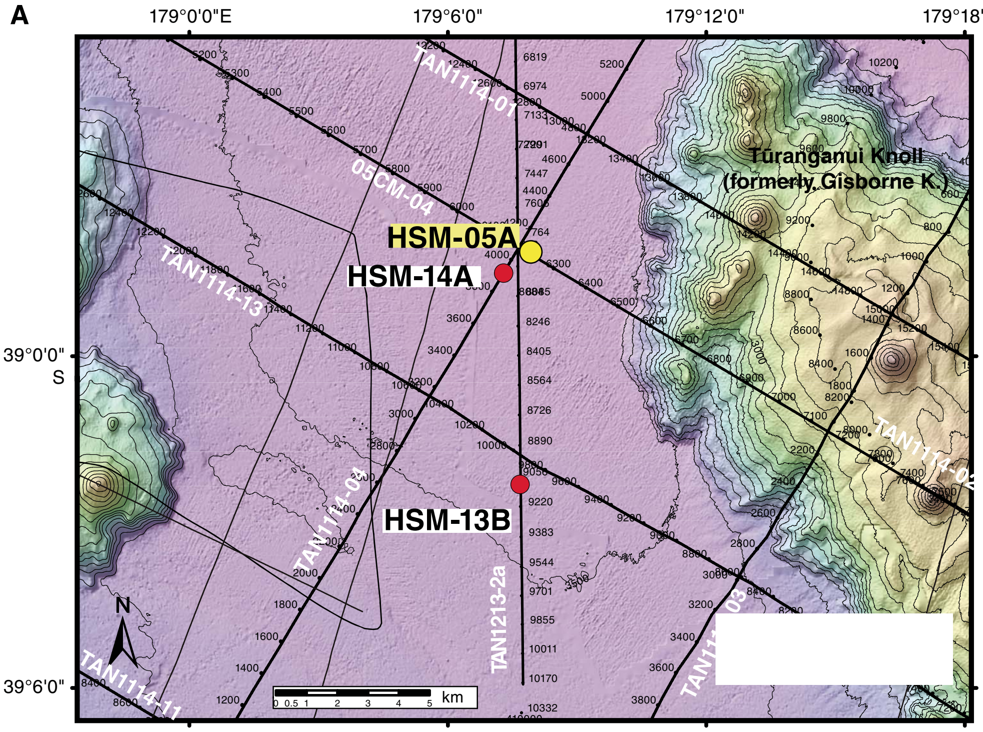


Figure F13. (A) Map and (B) regional seismic profile (TAN1213-02a) illustrating proposed primary inputs Site HSM-05A and proposed alternate Sites HSM-13B and HSM-14A (see seismic data on Figure **AF11** for Profile TAN1114-04).



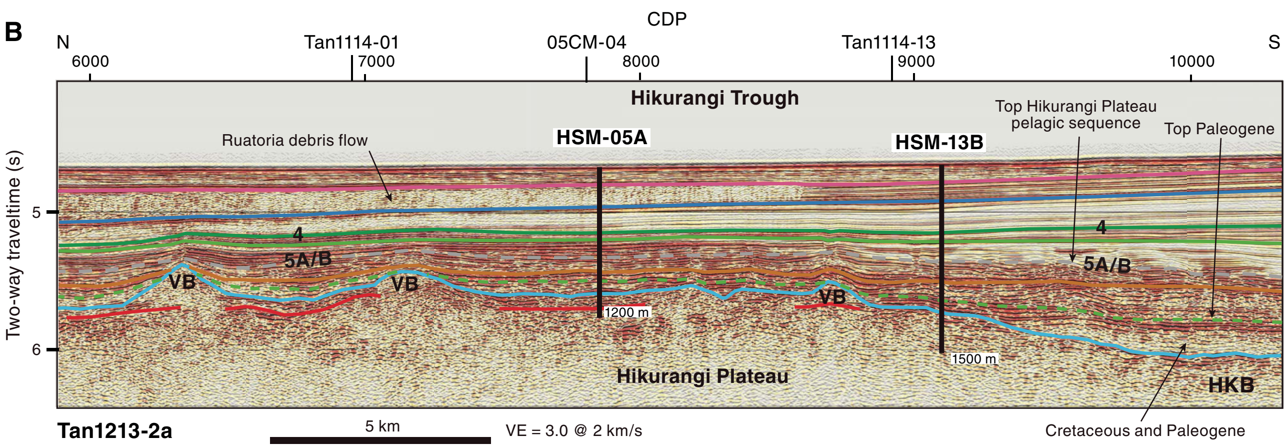


Figure F14. In-line across proposed Site TLC-01D (alternate to proposed Site TLC-04B) with interpretation.

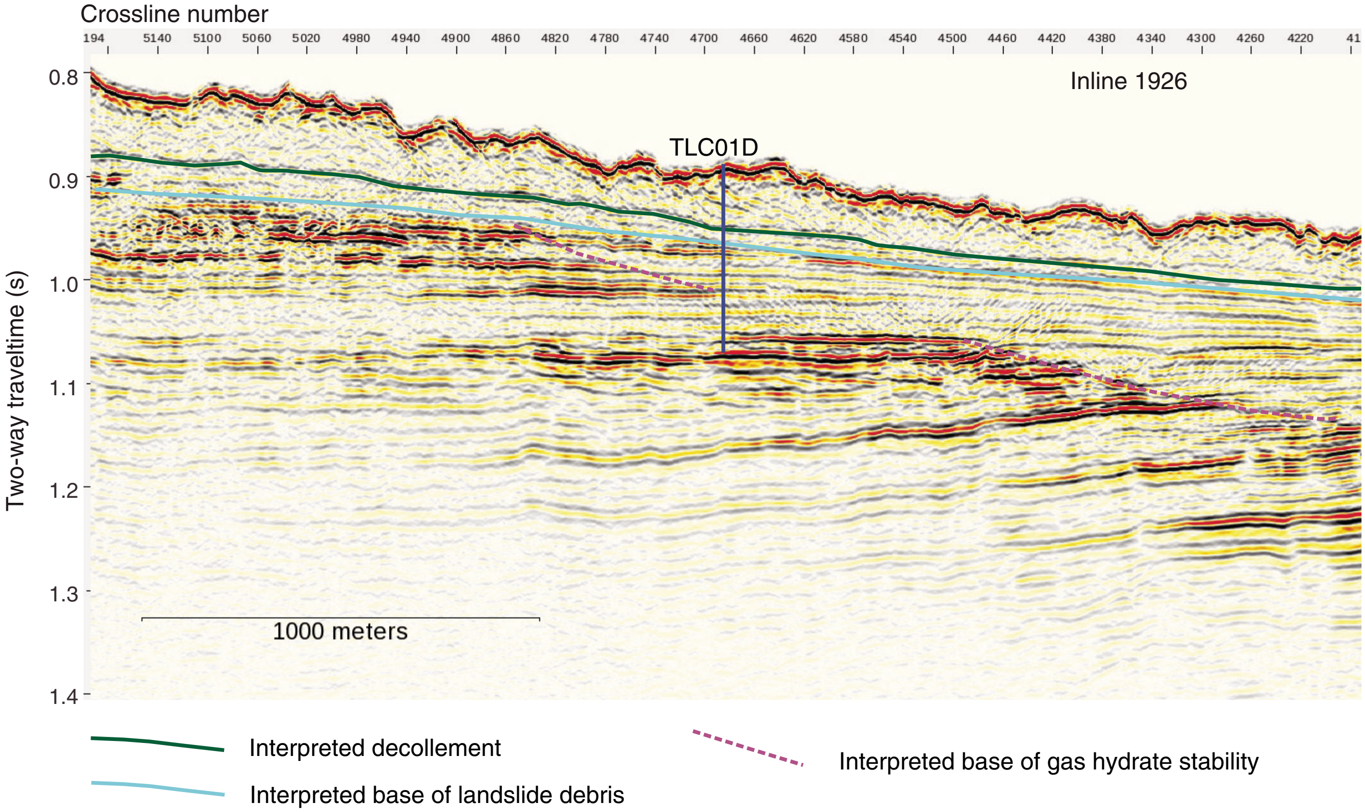


Figure F15. In-line across proposed Site TLC-05C (alternate to proposed Site TLC-04B) with interpretation.

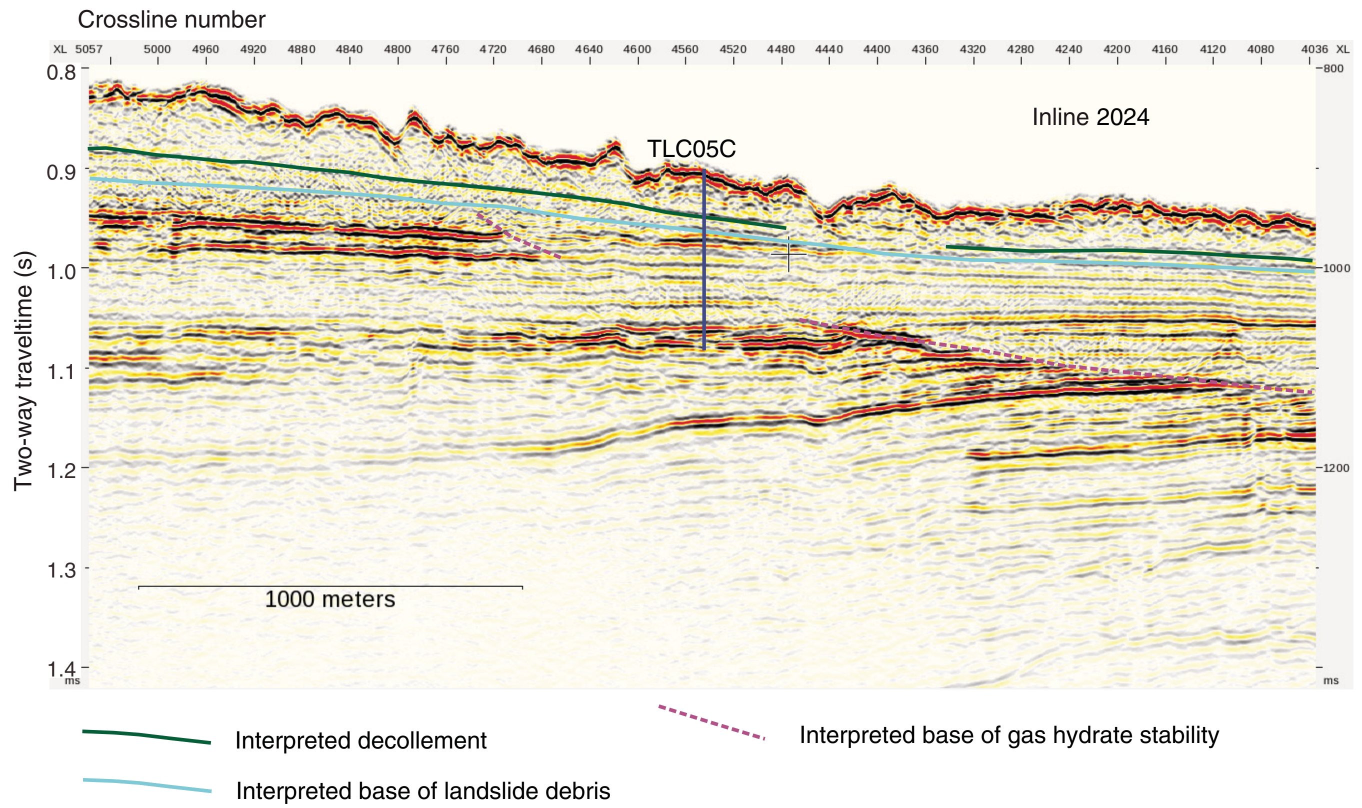


Figure F16. In-line across proposed Site TLC-06B (alternate to proposed Site TLC-02C) with interpretation.

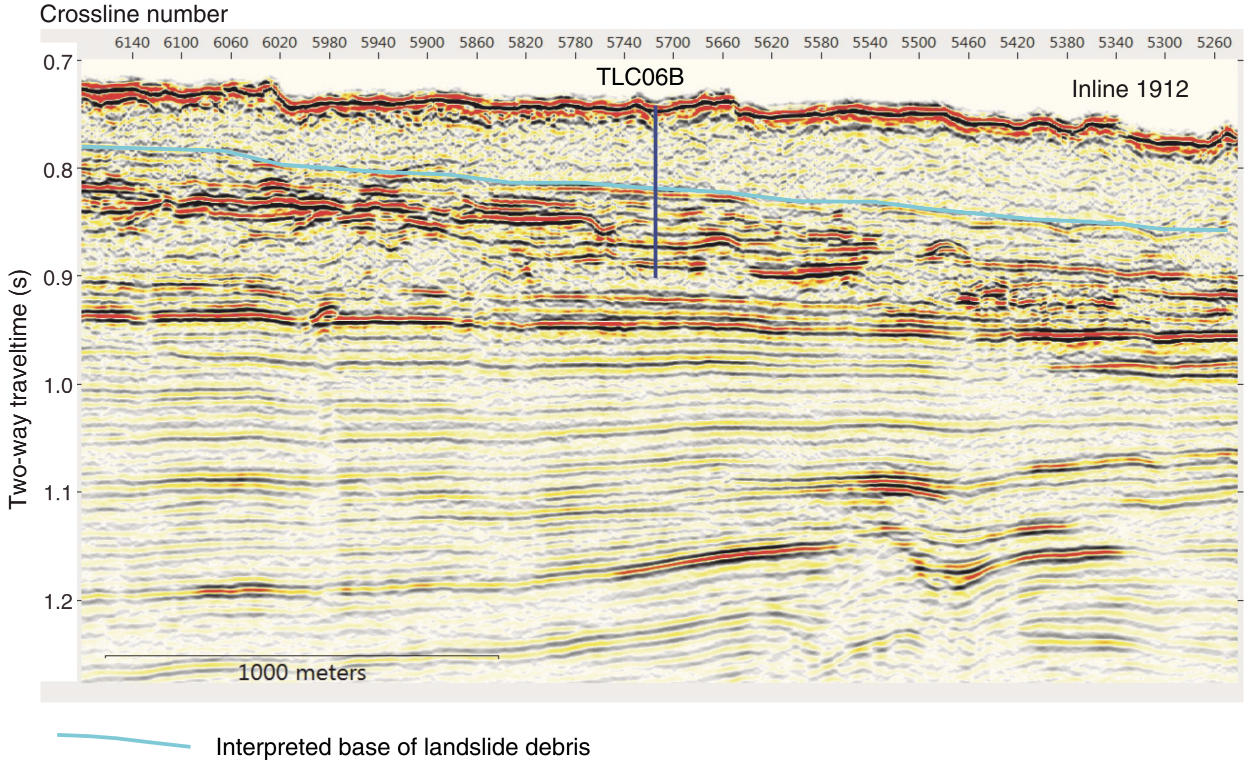


Figure F17. In-line across proposed Site TLC-07B (alternate to proposed Site TLC-02C) with interpretation.

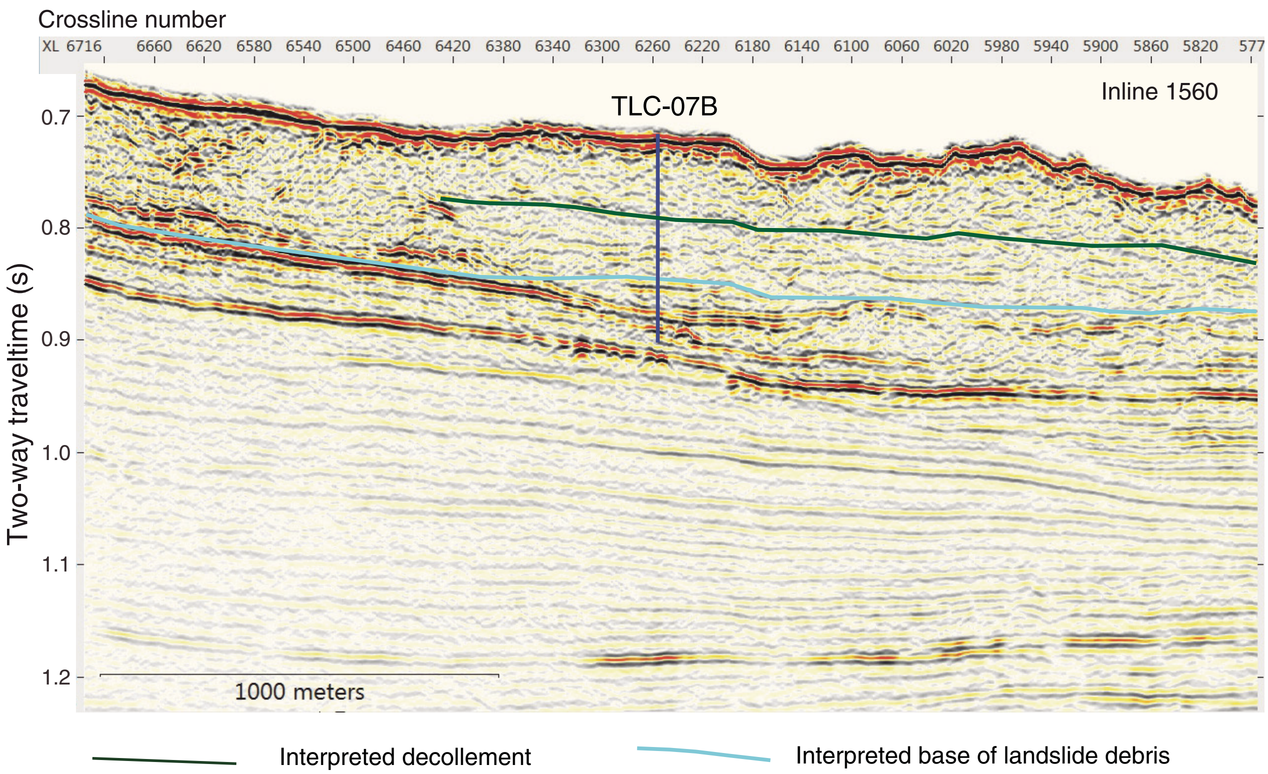
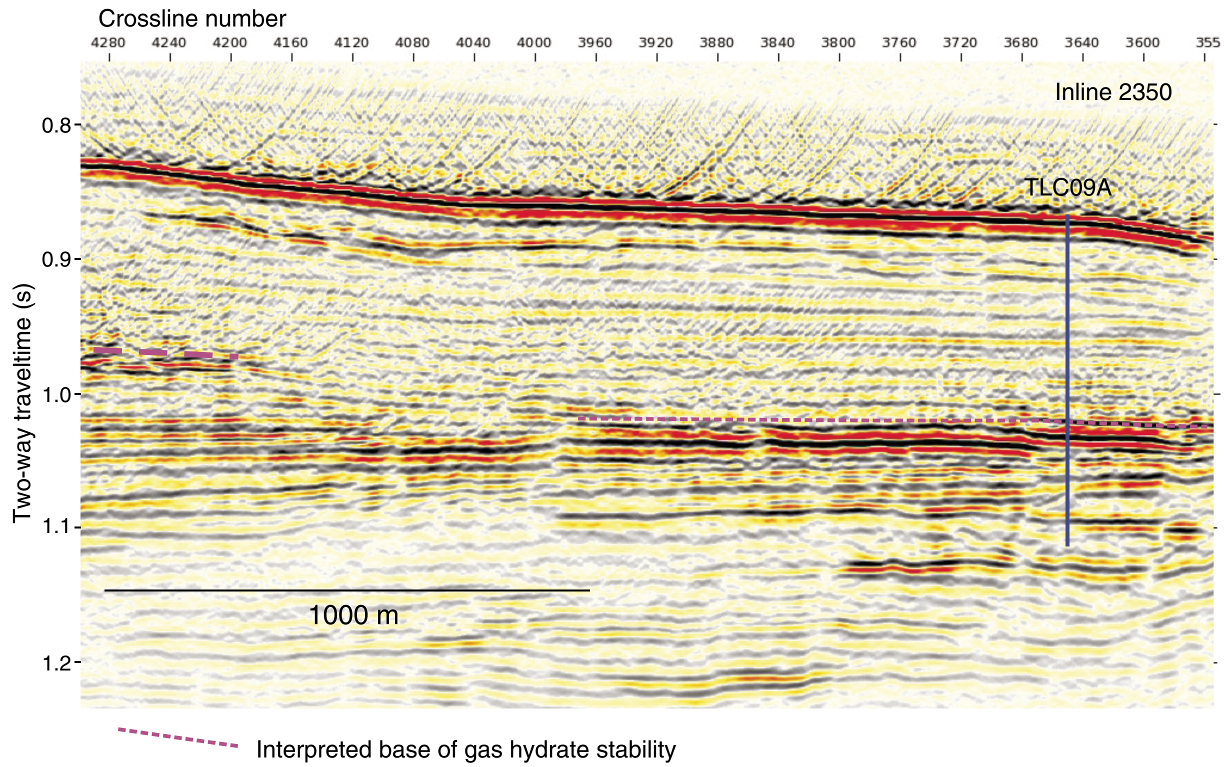


Figure F18. In-line across proposed Site TLC-09A (alternate to proposed Site TLC-03B) with interpretation.



Site summaries

Site TLC-04B

Priority:	Primary
Position:	38.829533°S, 178.475950°E
Water depth (m):	720
Target drilling depth (mbsf):	205
Approved maximum penetration (mbsf):	205
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 1778, cross-line 4225 Seismic profile and track map (Figure **AF1**)
Objective(s):	Determine presence of methane hydrates within landslide debris. Characterize distribution of hydrate. Determine overpressure at base of landslide debris and below hydrate stability. Collect pressure cores for shore-based studies of interstitial distribution of hydrates and mechanical properties.
Drilling program:	Hole A: LWD to 205 mbsf Hole B: APC/XCB to 190 mbsf Hole C: T2P/SETP and PCS at selected depths
Downhole measurements program:	LWD, APCT-3, T2P, SETP
Nature of rock anticipated:	Landslide debris, fine sandy coarse silt. Clayey silt, fine sandy mud.

Site TLC-02C

Priority:	Primary
Position:	38.792582°S, 178.447475°E
Water depth (m):	564
Target drilling depth (mbsf):	135
Approved maximum penetration (mbsf):	135
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 1942, cross-line 5749 Seismic profile and track map (Figure **AF2**)
Objective(s):	Determine if gas hydrate or free gas present. Determine potential overpressure.
Drilling program:	Hole A: LWD to 135 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Landslide debris, fine sandy coarse silt. Clayey silt, fine sandy mud.

Site TLC-03B

Priority:	Primary
Position:	38.826701°S, 178.503036°E
Water depth (m):	680
Target drilling depth (mbsf):	165
Approved maximum penetration (mbsf):	165
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 1052, cross-line 4000 Seismic profile and track map (Figure **AF3**)
Objective(s):	Determine properties of gas hydrate bearing sediments outside slide mass.
Drilling program:	Hole A: LWD to 165 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Clayey silt, fine sandy mud.

Site TLC-01D

Priority:	Alternate to TLC-04B
Position:	38.819567°S, 178.464117°E
Water depth (m):	669
Target drilling depth (mbsf):	155
Approved maximum penetration (mbsf):	155
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 1926, cross-line 4685 Seismic profile and track map (Figure **AF4**)
Objective(s):	Determine presence of methane hydrates within landslide debris. Characterize distribution of hydrate. Determine overpressure at base of landslide debris and below hydrate stability. Collect pressure cores for shore-based studies of interstitial distribution of hydrates and mechanical properties.
Drilling program:	Hole A: LWD to 155 mbsf Hole B: APC/XCB to 155 mbsf Hole C: T2P/SETP and PCS at selected depths
Downhole measurements program:	LWD, APCT-3, T2P, SETP
Nature of rock anticipated:	Landslide debris, fine sandy coarse silt. Clayey silt, fine sandy mud.

Site TLC-05C

Priority:	Alternate to TLC-04B
Position:	38.824303°S, 178.463040°E
Water depth (m):	677
Target drilling depth (mbsf):	155 (pending correction to EPSP minutes)
Approved maximum penetration (mbsf):	155 (pending correction to EPSP minutes)
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 2024, cross-line 4545 Seismic profile and track map (Figure **AF5**)
Objective(s):	Determine presence of methane hydrates within landslide debris. Characterize distribution of hydrate. Determine overpressure at base of landslide debris and below hydrate stability. Collect pressure cores for shore-based studies of interstitial distribution of hydrates and mechanical properties.
Drilling program:	Hole A: LWD to 155 mbsf Hole B: APC/XCB to 155 mbsf Hole C: T2P/SETP and PCS at selected depths
Downhole measurements program:	LWD, APCT-3, T2P, SETP
Nature of rock anticipated:	Landslide debris, fine sandy coarse silt. Clayey silt, fine sandy mud.

Site TLC-06B

Priority:	Alternate to TLC-02C
Position:	38.793123°S, 178.448984°E
Water depth (m):	568
Target drilling depth (mbsf):	135
Approved maximum penetration (mbsf):	135
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 1912, cross-line 5714 Seismic profile and track map (Figure **AF6**)
Objective(s):	Determine if gas hydrate or free gas present. Determine potential overpressure.
Drilling program:	Hole A: LWD to 135 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Landslide debris, fine sandy coarse silt. Clayey silt, fine sandy mud.

Site TLC-07B

Priority:	Alternate to TLC-02C
Position:	38.775106°S, 178.452262°E
Water depth (m):	548
Target drilling depth (mbsf):	155
Approved maximum penetration (mbsf):	155
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 1560, cross-line 6256 Seismic profile and track map (Figure **AF7**)
Objective(s):	Determine if gas hydrate or free gas present. Determine potential overpressure.
Drilling program:	Hole A: LWD to 135 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Landslide debris, fine sandy coarse silt. Clayey silt, fine sandy mud.

Site TLC-09A

Priority:	Alternate to TLC-03B
Position:	38.851026°S, 178.465965°E
Water depth (m):	663
Target drilling depth (mbsf):	195
Approved maximum penetration (mbsf):	195
Survey coverage (track map; seismic profile):	SCHLIP- 3-D in-line 2350, cross-line 3650 Seismic profile and track map (Figure **AF8**)
Objective(s):	Determine properties of gas hydrate bearing sediments outside slide mass.
Drilling program:	Hole A: LWD to 195 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Clayey silt, fine sandy mud.

Site HSM-01A

Priority:	Primary
Position:	38.727283°S, 178.614233°E
Water depth (m):	994
Target drilling depth (mbsf):	650
Approved maximum penetration (mbsf):	1180
Survey coverage (track map; seismic profile):	MCS Profiles 05CM-04, CDP 2037, and TAN1114-08, CDP 2040 Track map (Figure **F4**, **F10**, **AF9**) Seismic profile (Figures **F3**, **F4**, **F11**, **AF9**)
Objective(s):	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Inform selection of stratigraphic target for borehole observatory installation.
Drilling program:	Hole A: LWD to 650 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Upper slope and slope basin marine sandstone, siltstone, mudstone, MTDs, ash, and possibly calcareous sandstone and/or mudstone. Breccia intervals possible.

Site HSM-21B

Priority:	Alternate for HSM-01A.
Position:	38.720056°S, 178.618567°E
Water depth (m):	1011
Target drilling depth (mbsf):	650
Approved maximum penetration (mbsf):	1200
Survey coverage (track map; seismic profile):	MCS Profile TAN1114-08, CDP 1900 Track map (Figure **F4**, **F10**, **AF10**) Seismic profile (Figures **F11**, **AF10**)
Objective(s):	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Inform selection of stratigraphic target for borehole observatory installation.
Drilling program:	Hole A: LWD to 650 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Upper slope and slope basin marine sandstone, siltstone, mudstone, MTDs, ash, and possibly calcareous sandstone and/or mudstone. Breccia intervals possible.

Site HSM-22B

Priority:	Alternate for HSM-01A.
Position:	38.718228°S, 178.642544°E
Water depth (m):	1041
Target drilling depth (mbsf):	650
Approved maximum penetration (mbsf):	1200
Survey coverage (track map; seismic profile):	MCS Profile TAN1213-01, CDP 7000 Track map (Figure **F4**, **F10**, **AF11**) Seismic profile (Figures **F5**, **AF11**)
Objective(s):	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Inform selection of stratigraphic target for borehole observatory installation.
Drilling program:	Hole A: LWD to 650 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Upper slope and slope basin marine sandstone, siltstone, mudstone, MTDs, ash, and possibly calcareous sandstone and/or mudstone. Breccia intervals possible.

Site HSM-23B

Priority:	Alternate for HSM-01A.
Position:	38.717050°S, 178.649556°E
Water depth (m):	1045
Target drilling depth (mbsf):	650
Approved maximum penetration (mbsf):	1300
Survey coverage (track map; seismic profile):	MCS Profile TAN1213-01, CDP 7100 Track map (Figure **F4**, **F10**, **AF12**) Seismic profile (Figures **F11**, **AF12**)
Objective(s):	Coring and logging to assess physical properties and rock composition in the upper plate above SSE source region. Inform selection of stratigraphic target for borehole observatory installation.
Drilling program:	Hole A: LWD to 650 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Upper slope and slope basin marine sandstone, siltstone, mudstone, MTDs, ash, and possibly calcareous sandstone and/or mudstone. Breccia intervals possible.

Site HSM-18A

Priority:	Primary
Position:	38.871908°S, 178.939928°E
Water depth (m):	3168
Target drilling depth (mbsf):	700
Approved maximum penetration (mbsf):	800
Survey coverage (track map; seismic profile):	MCS Profile TAN1114-05, CDP 1678 Track map (Figure **F4**, **F12**, **AF13**) Seismic profile (Figures **F3**, **F12**, **AF13**)
Objective(s):	Establish shallow fault zone properties, composition, and conditions. Inform selection of stratigraphic target for borehole observatory installation. Thrust at 450 mbsf.
Drilling program:	Hole A: LWD to 700 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Lower slope sediments over accreted trench-fill turbidites and hemipelagic sediment; sandstone, siltstone, mudstone, and ash. Possibly MTDs.

Site HSM-15A

Priority:	Alternate for HSM-18A.
Position:	38.858944°S, 178.896006°E
Water depth (m):	2724
Target drilling depth (mbsf):	600
Approved maximum penetration (mbsf):	600
Survey coverage (track map; seismic profile):	MCS Profile 05CM-04, CDP 4319 Track map (Figure **F4**, **F12**, **AF14**) Seismic profile (Figures **F3**, **F12**, **AF14**)
Objective(s):	Establish shallow fault zone properties, composition, and conditions. Inform selection of stratigraphic target for borehole observatory installation. Thrust at 325 mbsf.
Drilling program:	Hole A: LWD to 600 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Lower slope sediments over accreted trench-fill turbidites and hemipelagic sediment; sandstone, siltstone, mudstone, and ash. Possibly MTDs.

Site HSM-16B

Priority:	Alternate for HSM-18A.
Position:	38.913406°S, 178.906842°E
Water depth (m):	2432
Target drilling depth (mbsf):	1350
Approved maximum penetration (mbsf):	1350
Survey coverage (track map; seismic profile):	MCS Profile TAN1114-05, CDP 2550 Track map (Figure **F4**, **F12**, **AF15**) Seismic profile (Figures **F12**, **AF15**)
Objective(s):	Establish shallow fault zone properties, composition, and conditions. Inform selection of stratigraphic target for borehole observatory installation. Thrust at 1055 mbsf.
Drilling program:	Hole A: LWD to 1350 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Lower slope sediments over accreted trench-fill turbidites and hemipelagic sediment; sandstone, siltstone, mudstone, and ash. Possibly MTDs.

Site HSM-19B

Priority:	Alternate for HSM-18A.
Position:	38.836100°S, 178.943903°E
Water depth (m):	3024
Target drilling depth (mbsf):	1100
Approved maximum penetration (mbsf):	1100
Survey coverage (track map; seismic profile):	MCS Profile TAN1114-01, CDP 9700 Track map (Figure **F4**, **F12**, **AF16**) Seismic profile (Figures **F12**, **AF16**)
Objective(s):	Establish shallow fault zone properties, composition, and conditions. Inform selection of stratigraphic target for borehole observatory installation. Thrusts at 887–964 mbsf.
Drilling program:	Hole A: LWD to 1100 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Lower slope sediments over accreted trench-fill turbidites and hemipelagic sediment; sandstone, siltstone, mudstone, and ash. Possibly MTDs.

Site HSM-05A

Priority:	Primary
Position:	38.969400°S, 179.132250°E
Water depth (m):	3538
Target drilling depth (mbsf):	1200
Approved maximum penetration (mbsf):	1400
Survey coverage (track map; seismic profile):	MCS Profile 05CM-04, CDP 6229, and TAN1114-04, CDP 4076 Track map (Figure **F4**, **F13**, **AF17**) Seismic profile (Figures **F13**, **AF17**)
Objective(s):	Characterize the age, lithology, and physical and thermal properties of the sedimentary sequence and underlying volcanic basement on the subducting plate. Hikurangi Plateau volcanic sequence at 890 mbsf.
Drilling program:	Hole A: LWD to 1200 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Sandstone–mudstones turbidites, MTDs, ash, and hemipelagic sediment over nannofossil-rich pelagic mudstones, chalk, ash, possibly siliceous chert, and volcanic rocks of the Hikurangi Plateau.

Site HSM-13B

Priority:	Alternate for HSM-05A.
Position:	39.038806°S, 179.128058°E
Water depth (m):	3508
Target drilling depth (mbsf):	1500
Approved maximum penetration (mbsf):	1500
Survey coverage (track map; seismic profile):	MCS Profile TAN1213-02a, CDP 9100 Track map (Figure **F4**, **F13**, **AF18**) Seismic profile (Figures **F13**, **AF18**)
Objective(s):	Characterize the age, lithology, and physical and thermal properties of the sedimentary sequence and underlying volcanic basement on the subducting plate. Hikurangi Plateau volcanic sequence at 1245 mbsf.
Drilling program:	Hole A: LWD to 1500 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Sandstone–mudstones turbidites, MTDs, ash, and hemipelagic sediment over nannofossil-rich pelagic mudstones, chalk, ash, possibly siliceous chert, and volcanic rocks of the Hikurangi Plateau.

Site HSM-14A

Priority:	Alternate for HSM-05A.
Position:	38.974919°S, 179.121542°E
Water depth (m):	3531
Target drilling depth (mbsf):	1300
Approved maximum penetration (mbsf):	1300
Survey coverage (track map; seismic profile):	MCS Profile TAN1114-04, CDP 3915 Track map (Figure **F4**, **F13**, **AF19**) Seismic profile (Figures **AF19**)
Objective(s):	Characterize the age, lithology, and physical and thermal properties of the sedimentary sequence and underlying volcanic basement on the subducting plate. Hikurangi Plateau volcanic sequence at 987 mbsf.
Drilling program:	Hole A: LWD to 1300 mbsf
Downhole measurements program:	LWD
Nature of rock anticipated:	Sandstone–mudstones turbidites, MTDs, ash, and hemipelagic sediment over nannofossil-rich pelagic mudstones, chalk, ash, possibly siliceous chert, and volcanic rocks of the Hikurangi Plateau.

Figure AF1. In-lines and cross-lines across proposed primary Site TLC-04B with interpretation and tracks.

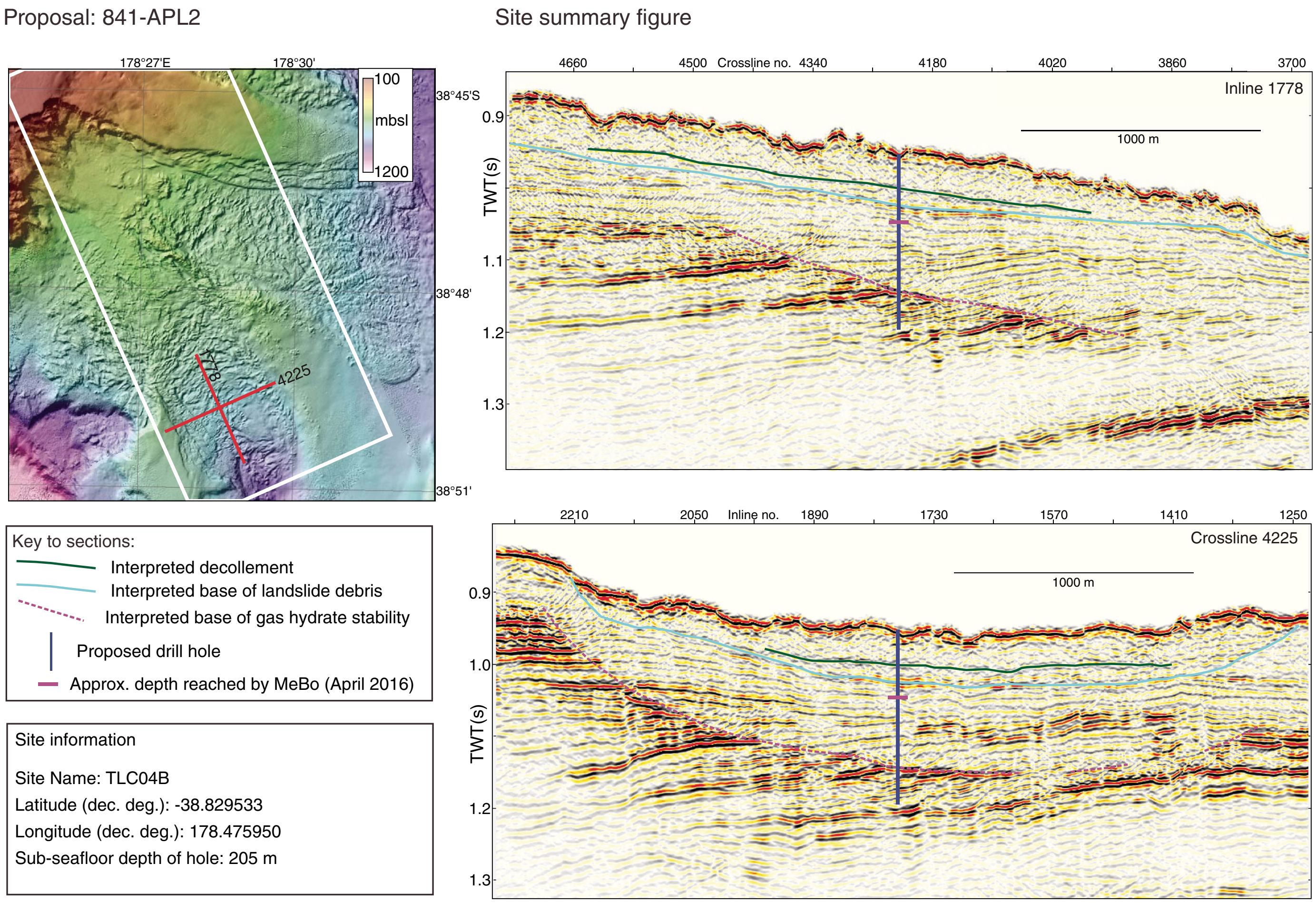


Figure AF2. In-lines and cross-lines across proposed primary Site TLC-02C with interpretation and tracks.

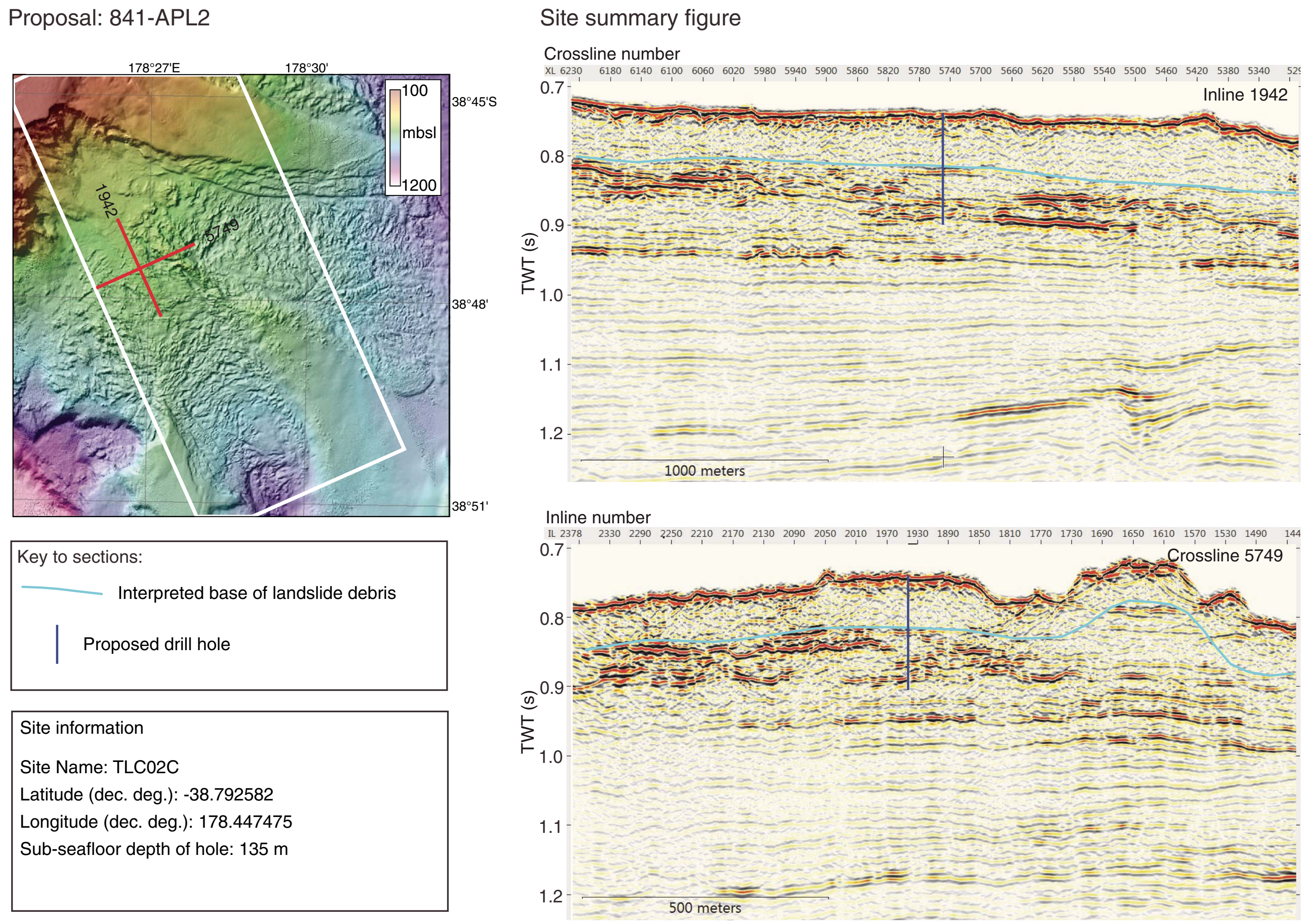


Figure AF3. In-lines and cross-lines across proposed primary Site TLC-03B with interpretation and tracks.

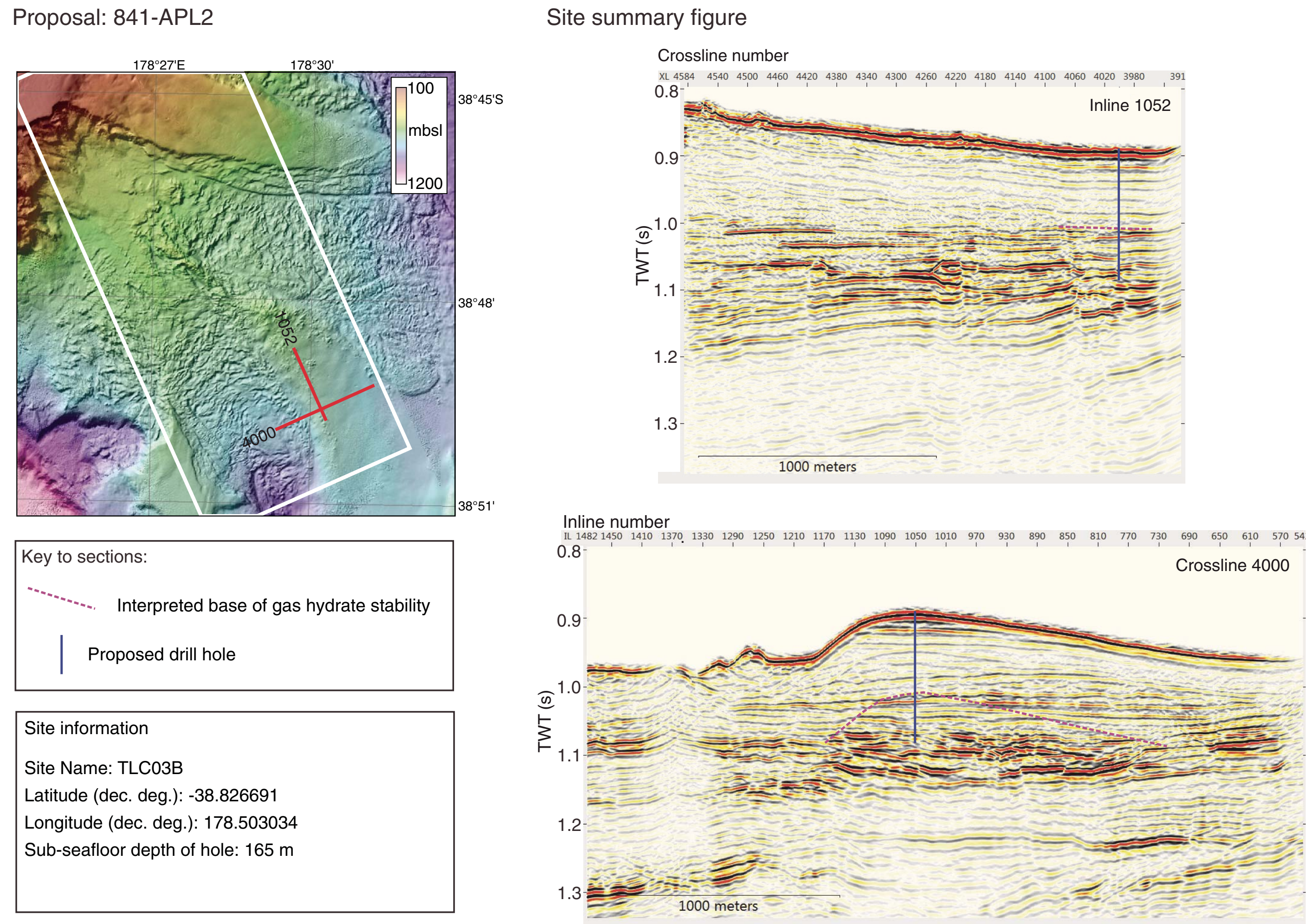


Figure AF4. In-lines and cross-lines across proposed Site TLC-01D (alternate to proposed Site TLC-04B) with interpretation and tracks.

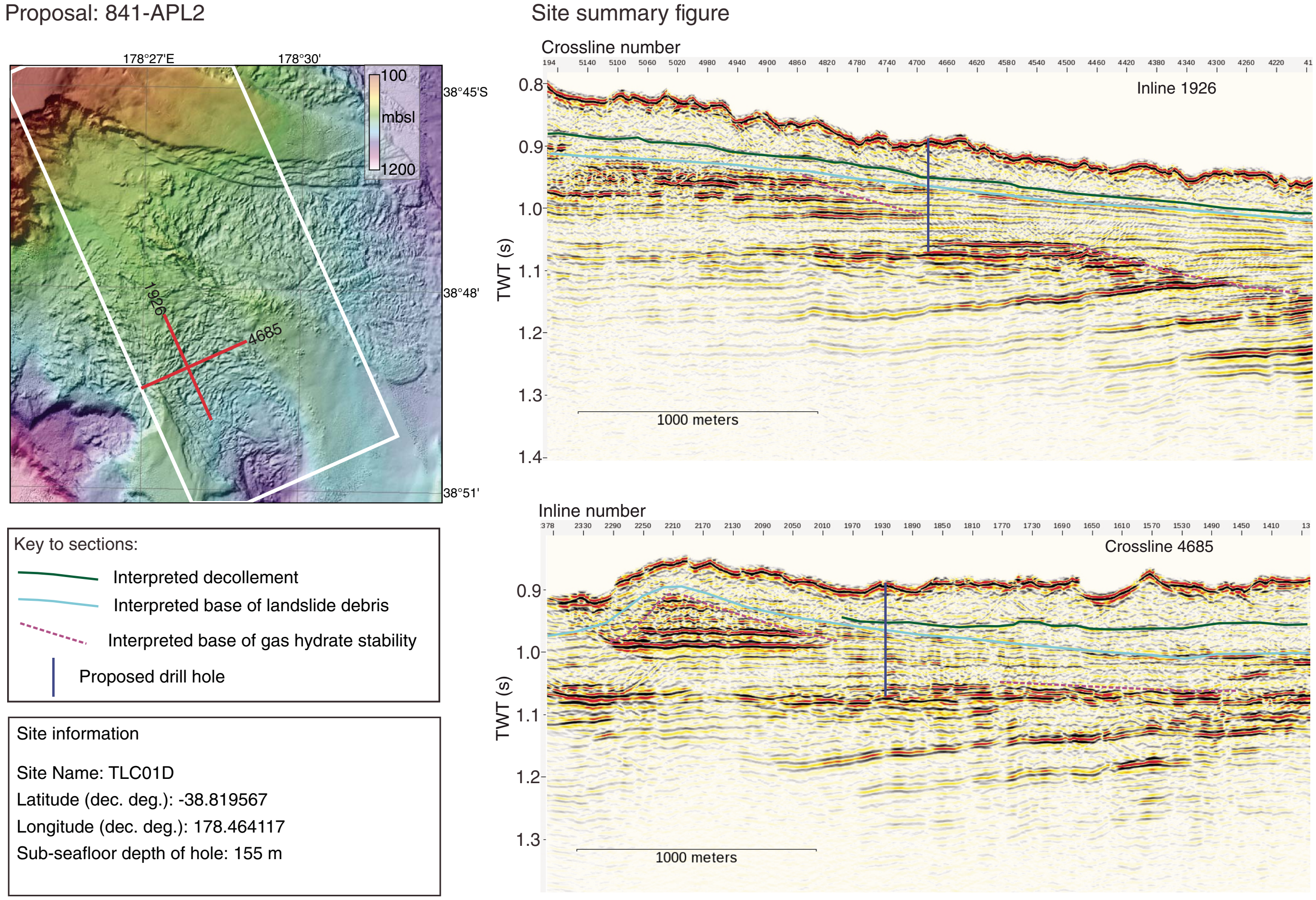


Figure AF5. In-lines and cross-lines across proposed Site TLC-05C (alternate to proposed Site TLC-04B) with interpretation and tracks.

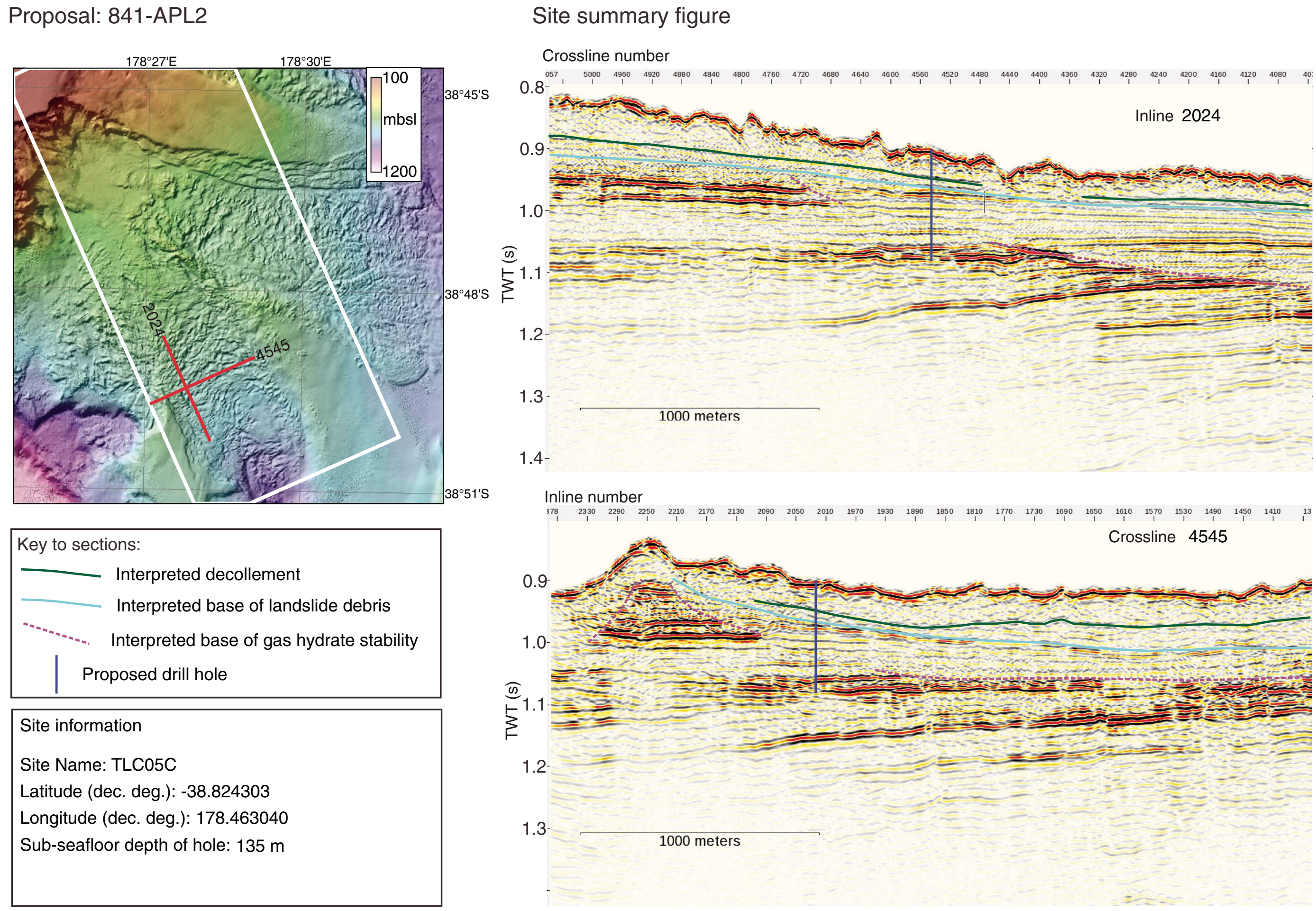


Figure AF6. In-lines and cross-lines across proposed Site TLC-06B (alternate to proposed Site TLC-02C) with interpretation and tracks.

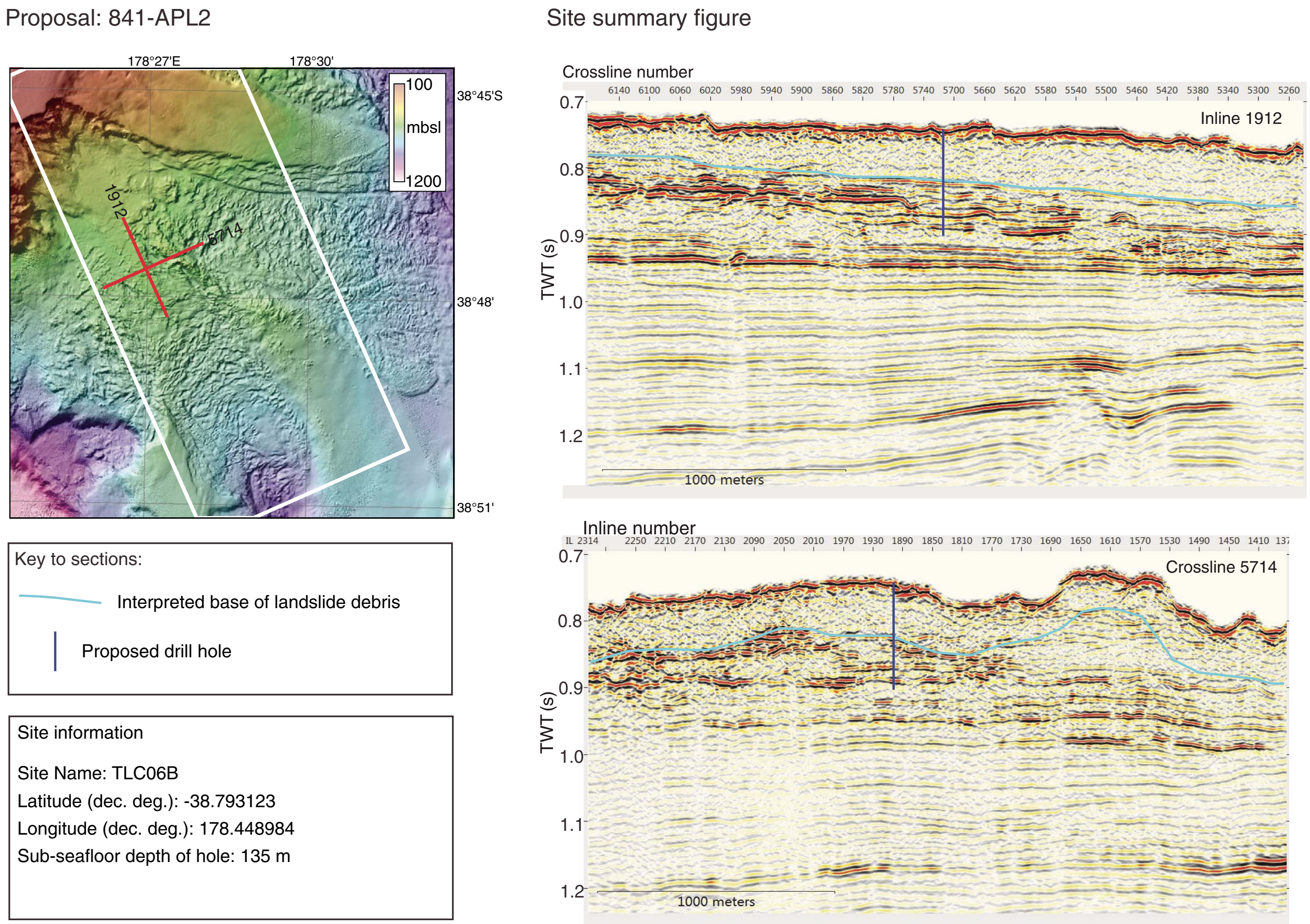


Figure AF7. In-lines and cross-lines across proposed Site TLC-07B (alternate to proposed Site TLC-02C) with interpretation and tracks.

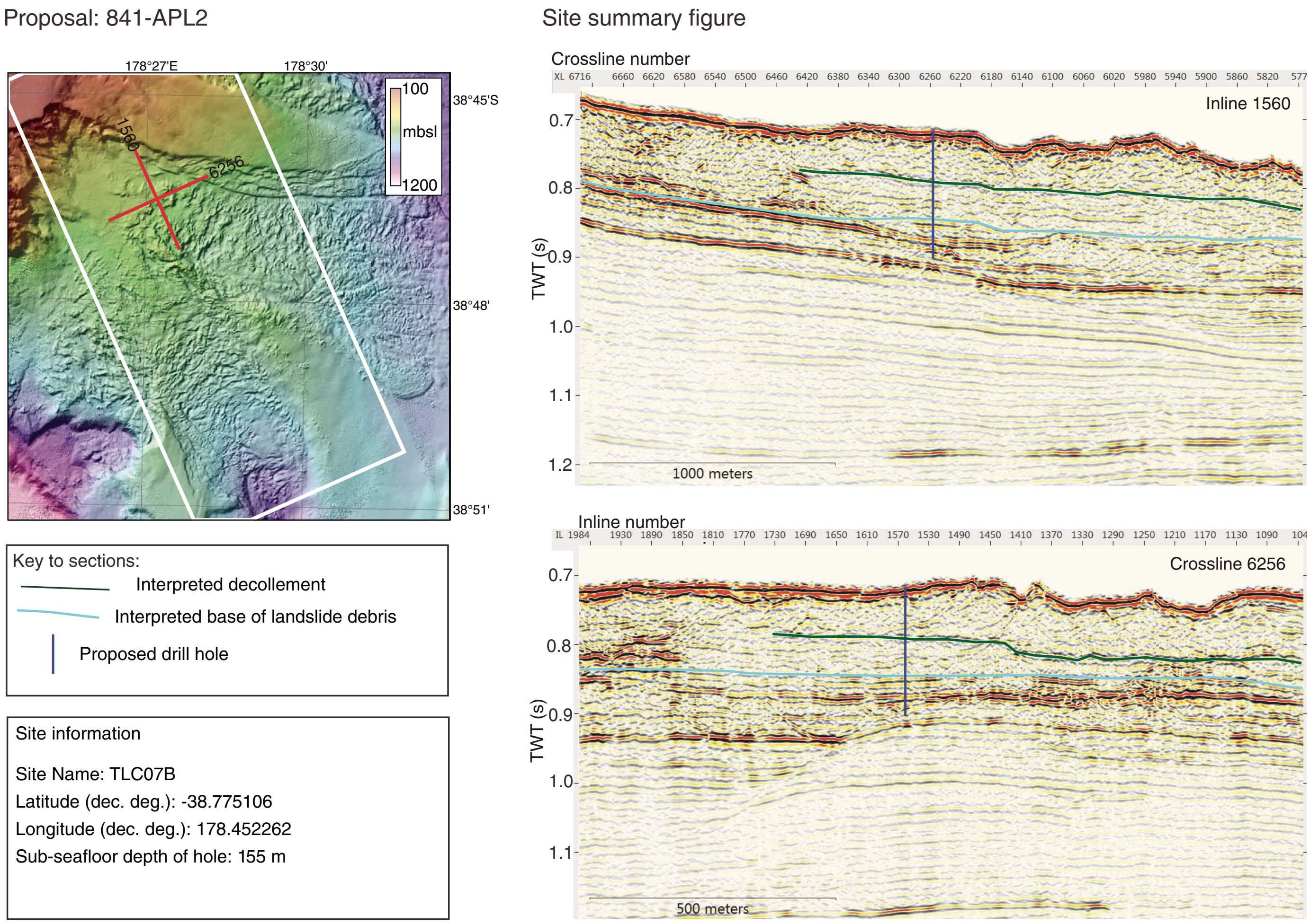
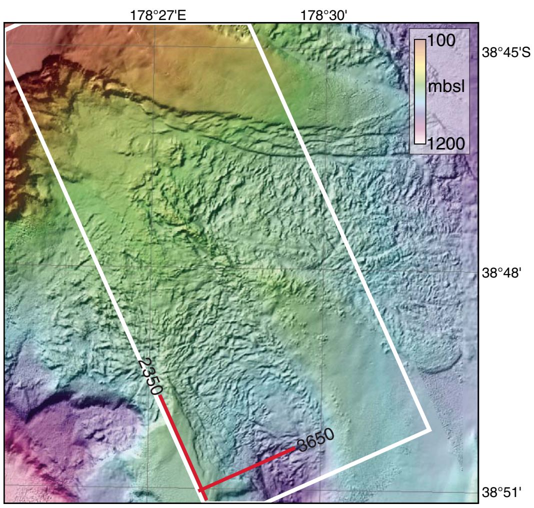


Figure AF8. In-lines and cross-lines across proposed Site TLC-09A (alternate to proposed Site TLC-03B) with interpretation and tracks.

Proposal: 841-APL2

Site summary figure



Key to sections:

Interpreted base of landslide

Interpreted base of gas hydrate stability

Proposed drill hole

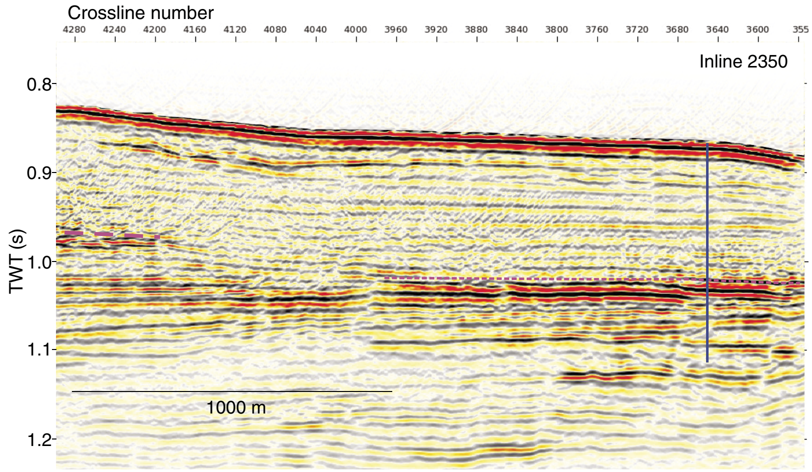
Site information

Site Name: TLC09A

Latitude (dec. deg.): -38.851026

Longitude (dec. deg.): 178.465965

Sub-seafloor depth of hole: 195 m



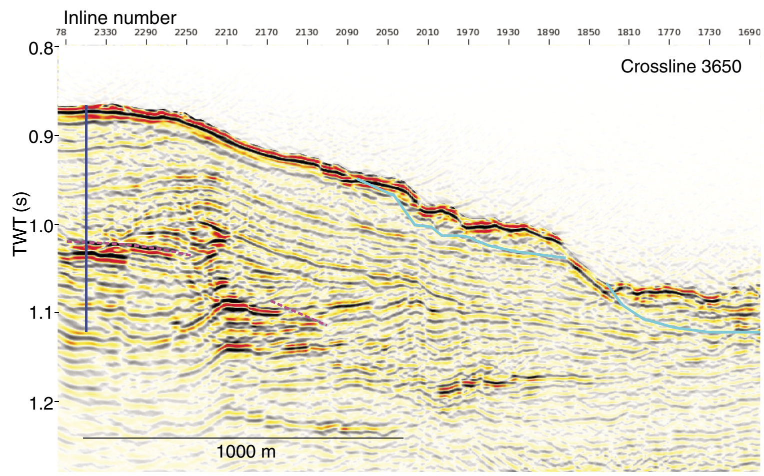


Figure AF9. Details of proposed primary Site HSM-01A. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Sections 05CM-04 and TAN1114-08.

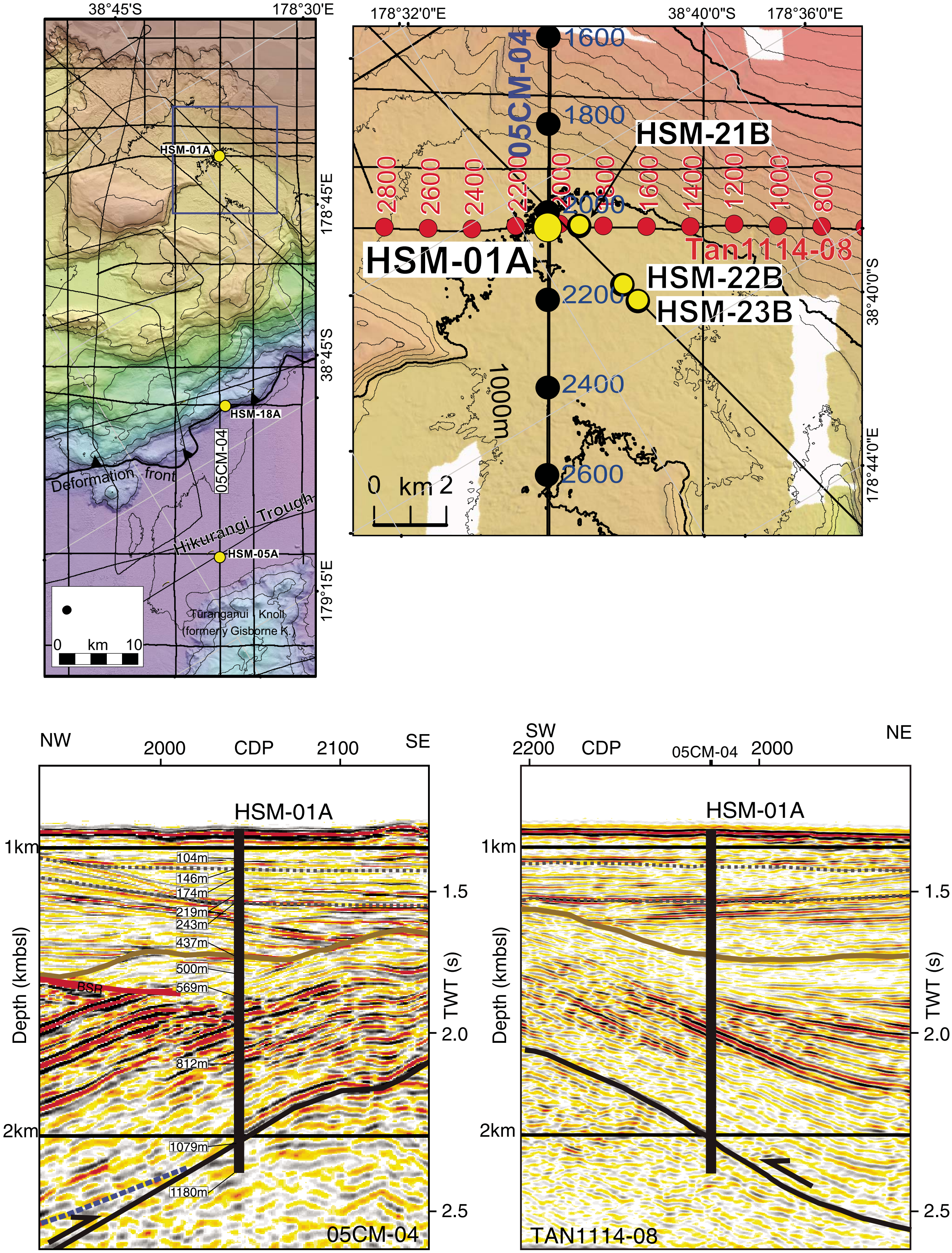


Figure AF10. Details of proposed alternate Site HSM-21B. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Section TAN1114-08.

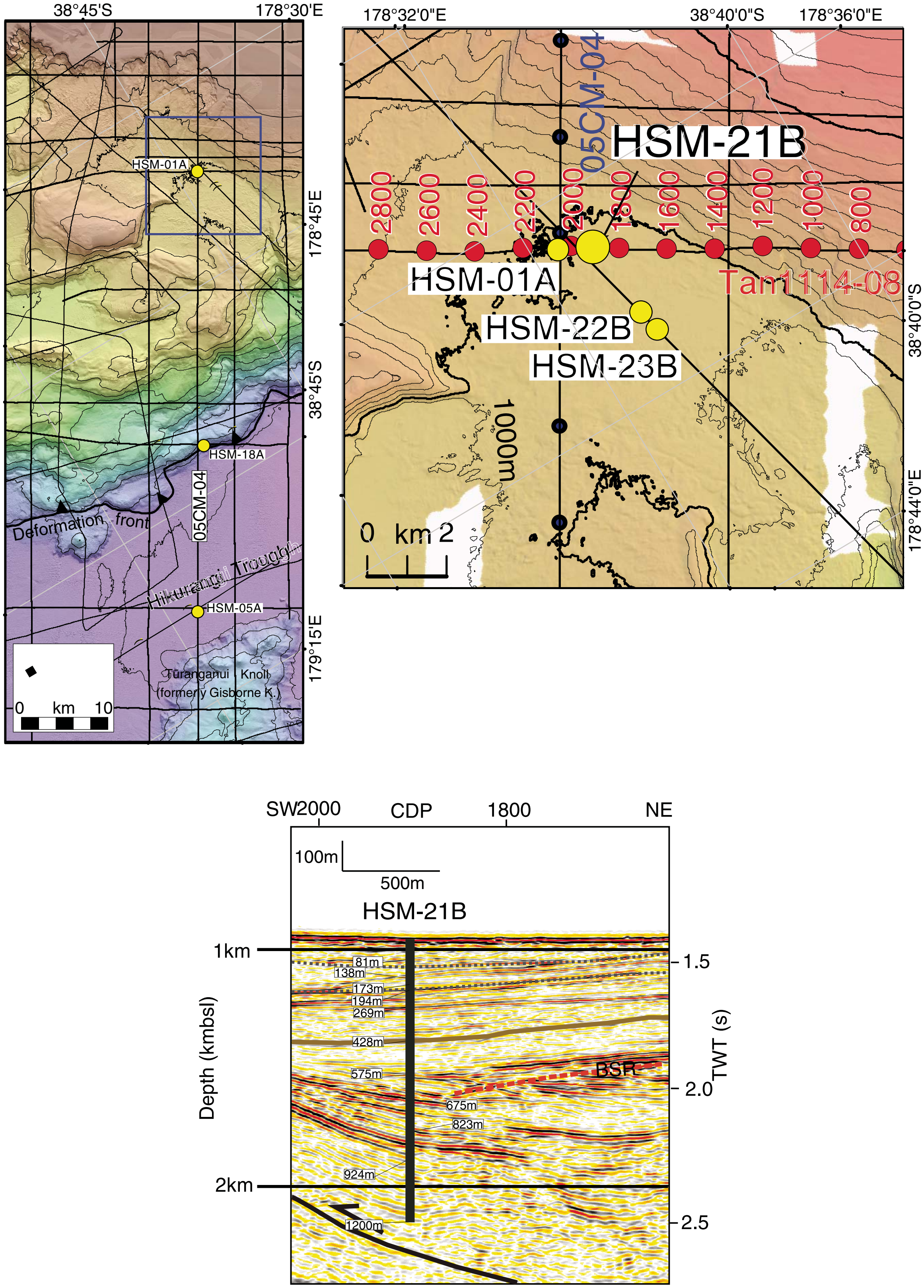


Figure AF11. Details of proposed alternate Site HSM-22B. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Section TAN1213-01.

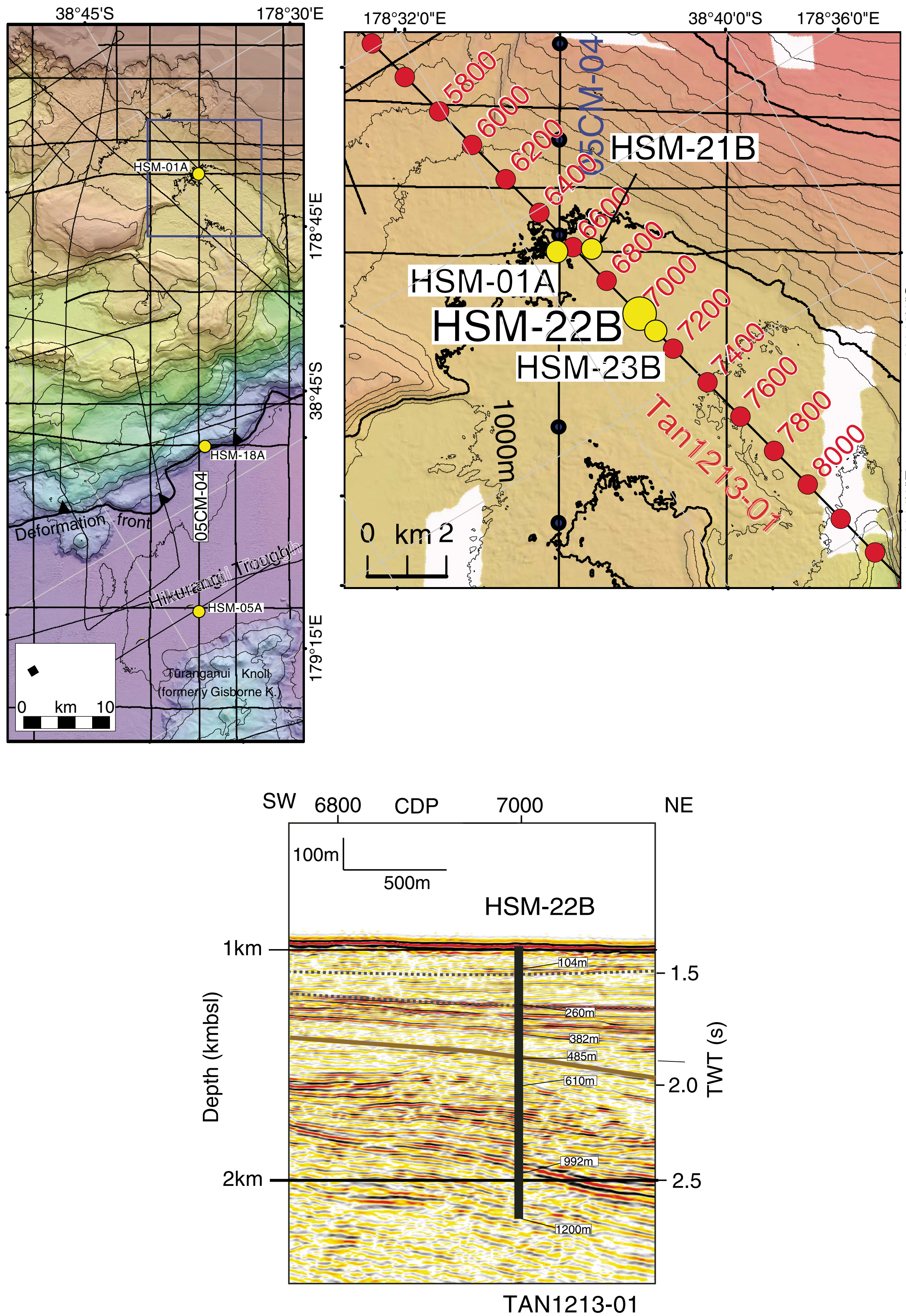


Figure AF12. Details of proposed alternate Site HSM-23B. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Section TAN1213-01.

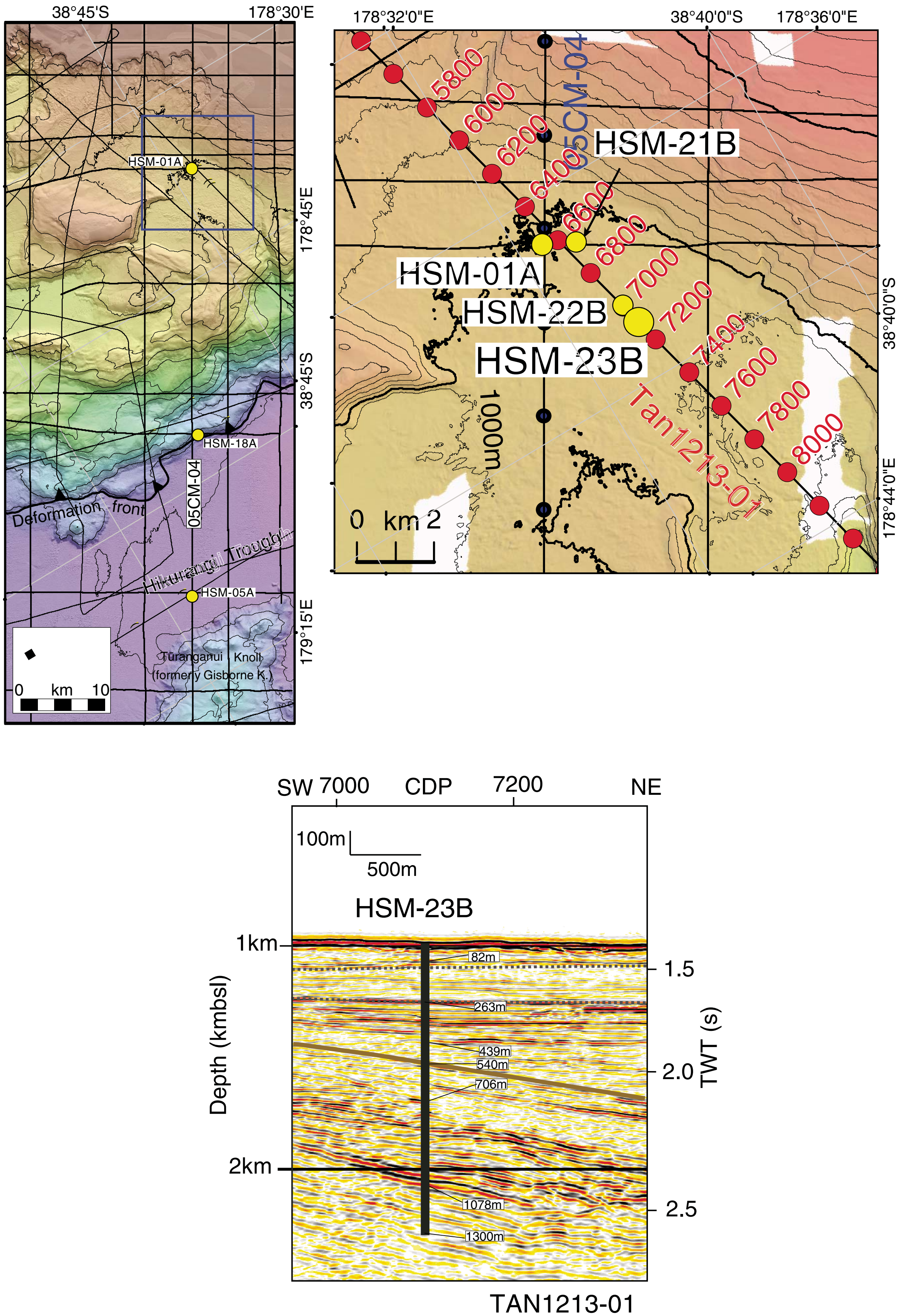


Figure AF13. Details of proposed primary Site HSM-18A. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Section TAN1114-05.

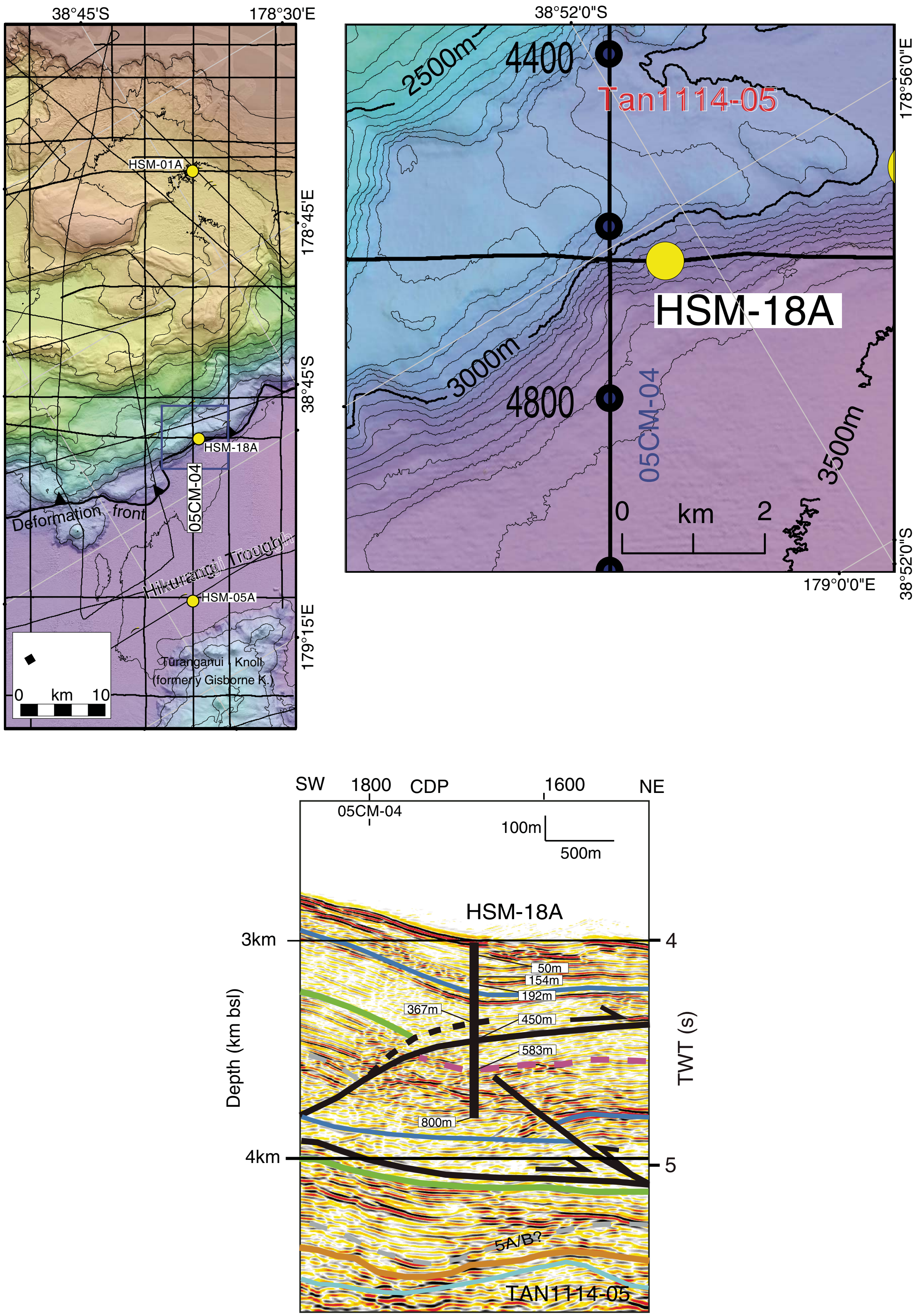


Figure AF14. Details of proposed alternate Site HSM-15A. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Sections 05CM-04 and TAN1114-06.

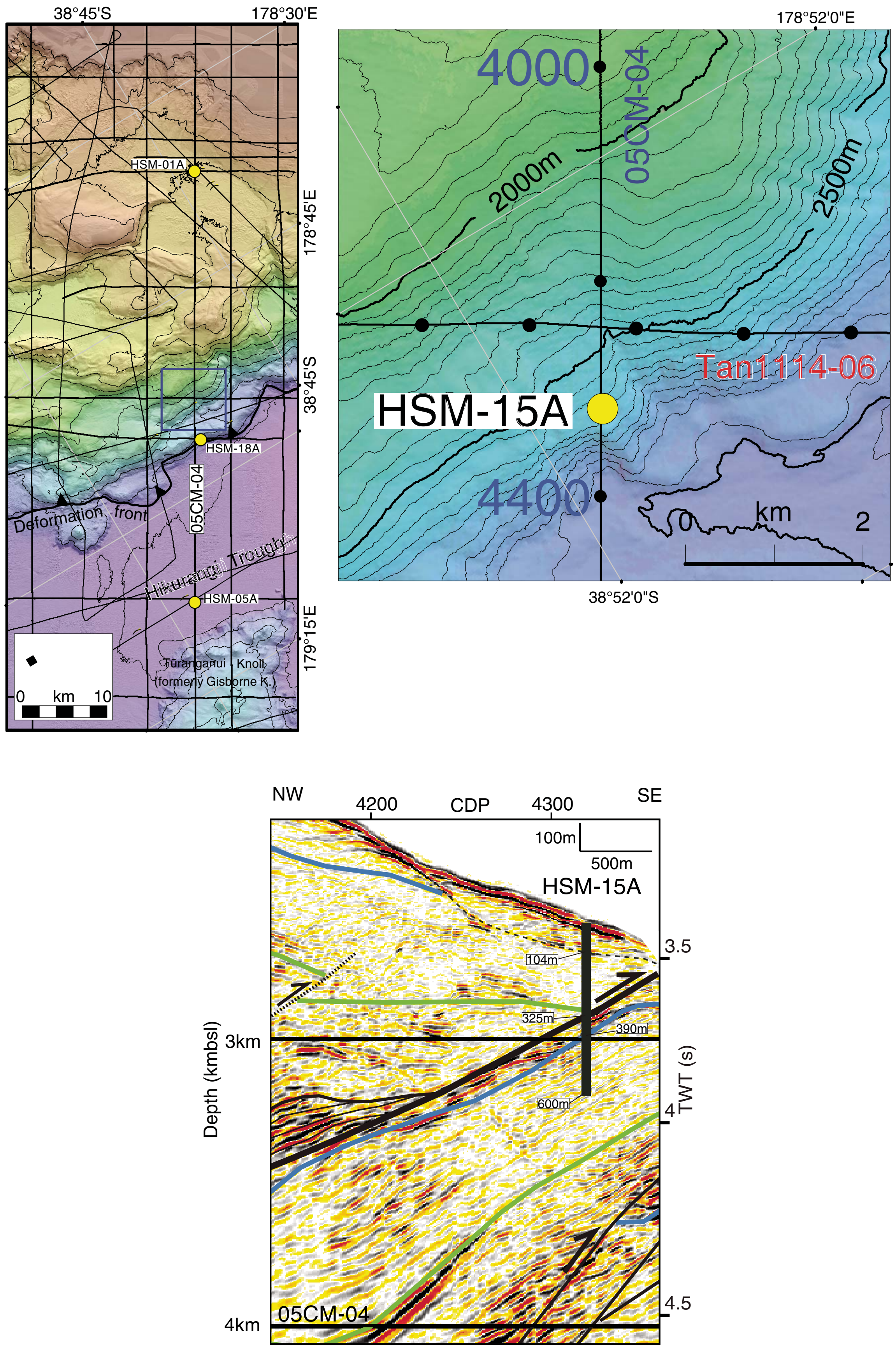


Figure AF15. Details of proposed alternate Site HSM-16B. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Section TAN1114-05.

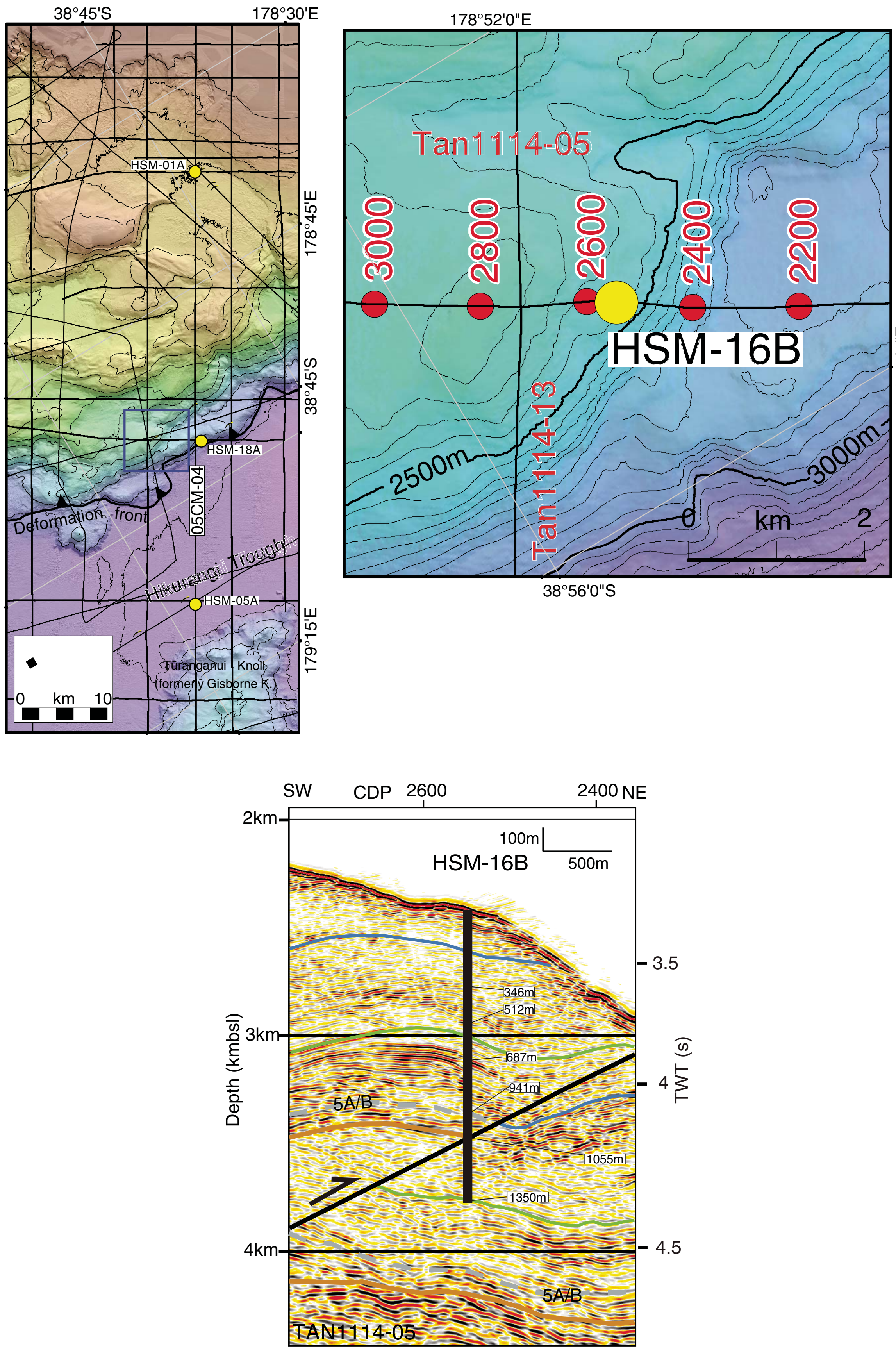


Figure AF16. Details of proposed alternate Site HSM-19B. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: Site position on seismic Section TAN1114-01.

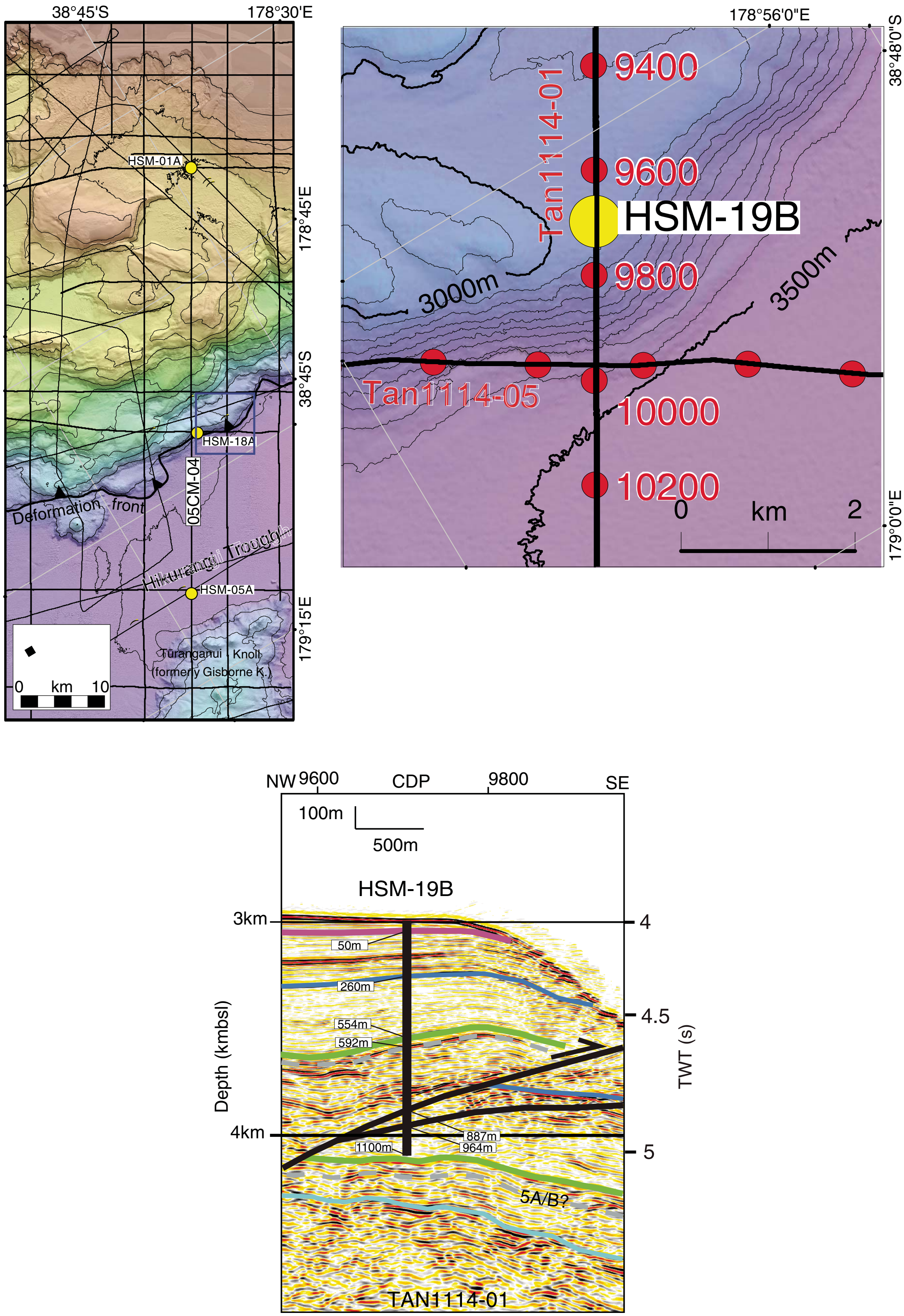


Figure AF17. Details of proposed primary Site HSM-05A. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. (Continued on next page.)

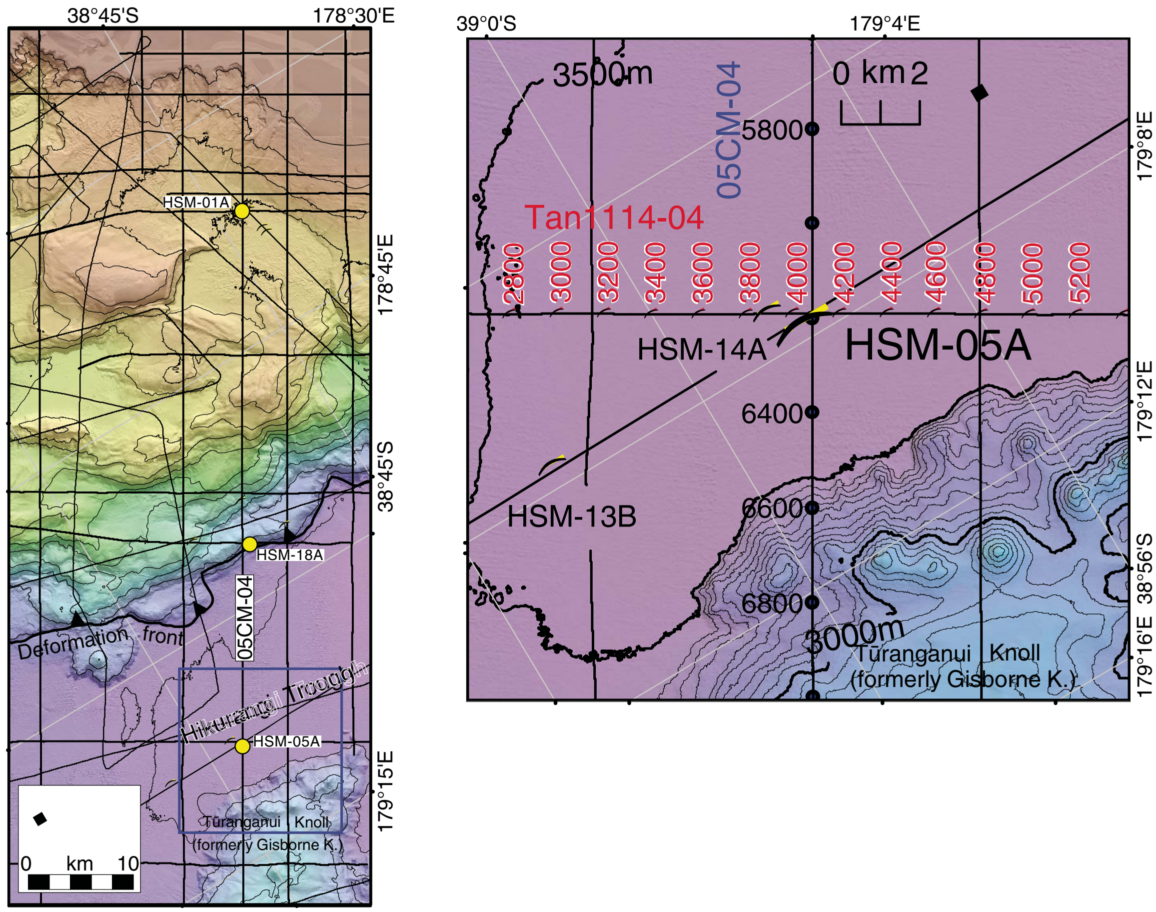


Figure AF17 (continued). Site position on seismic Section 05CM-04 and projected to TAN1114-04.

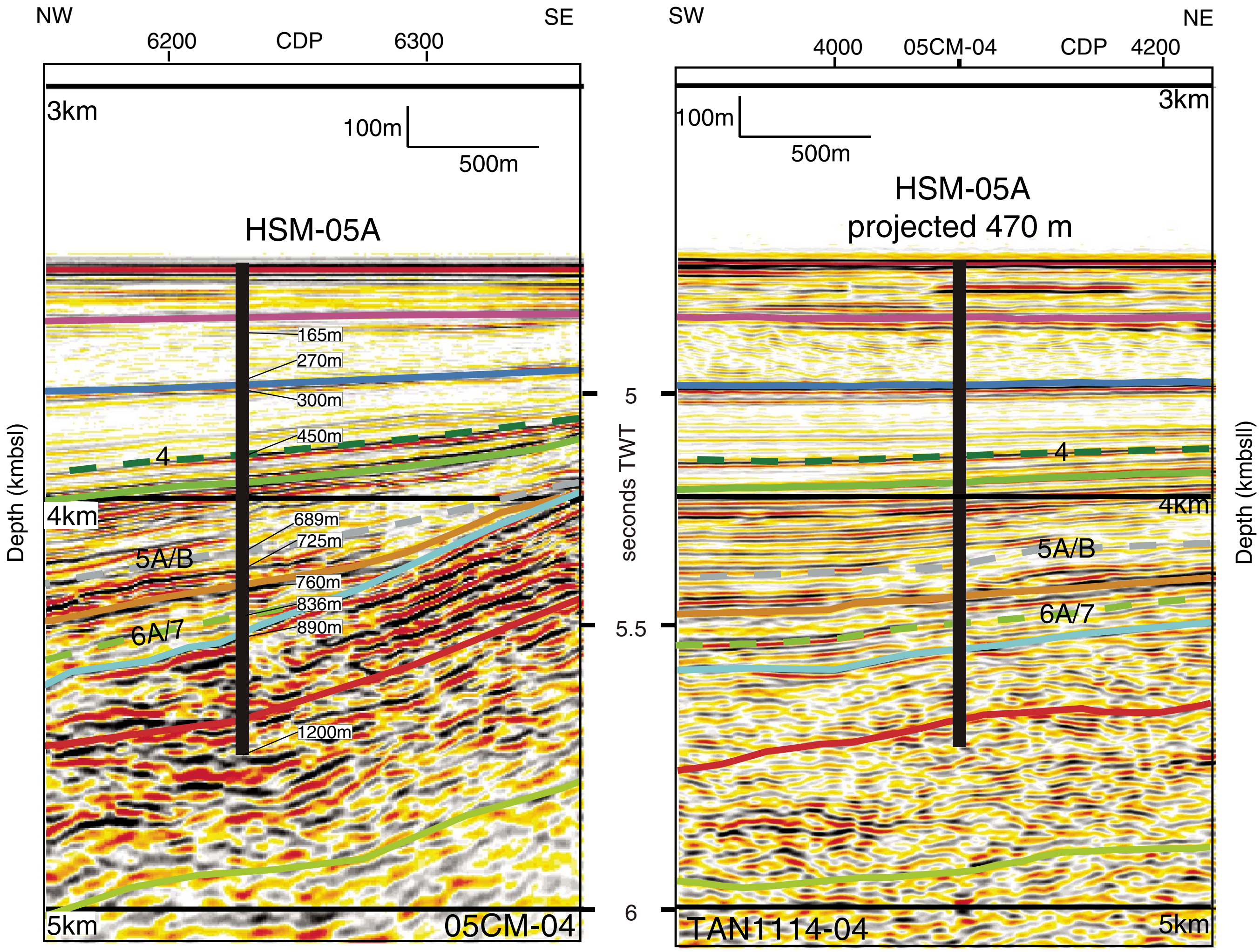


Figure AF18. Details of proposed alternate Site HSM-13B. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Section TAN1213-02a.

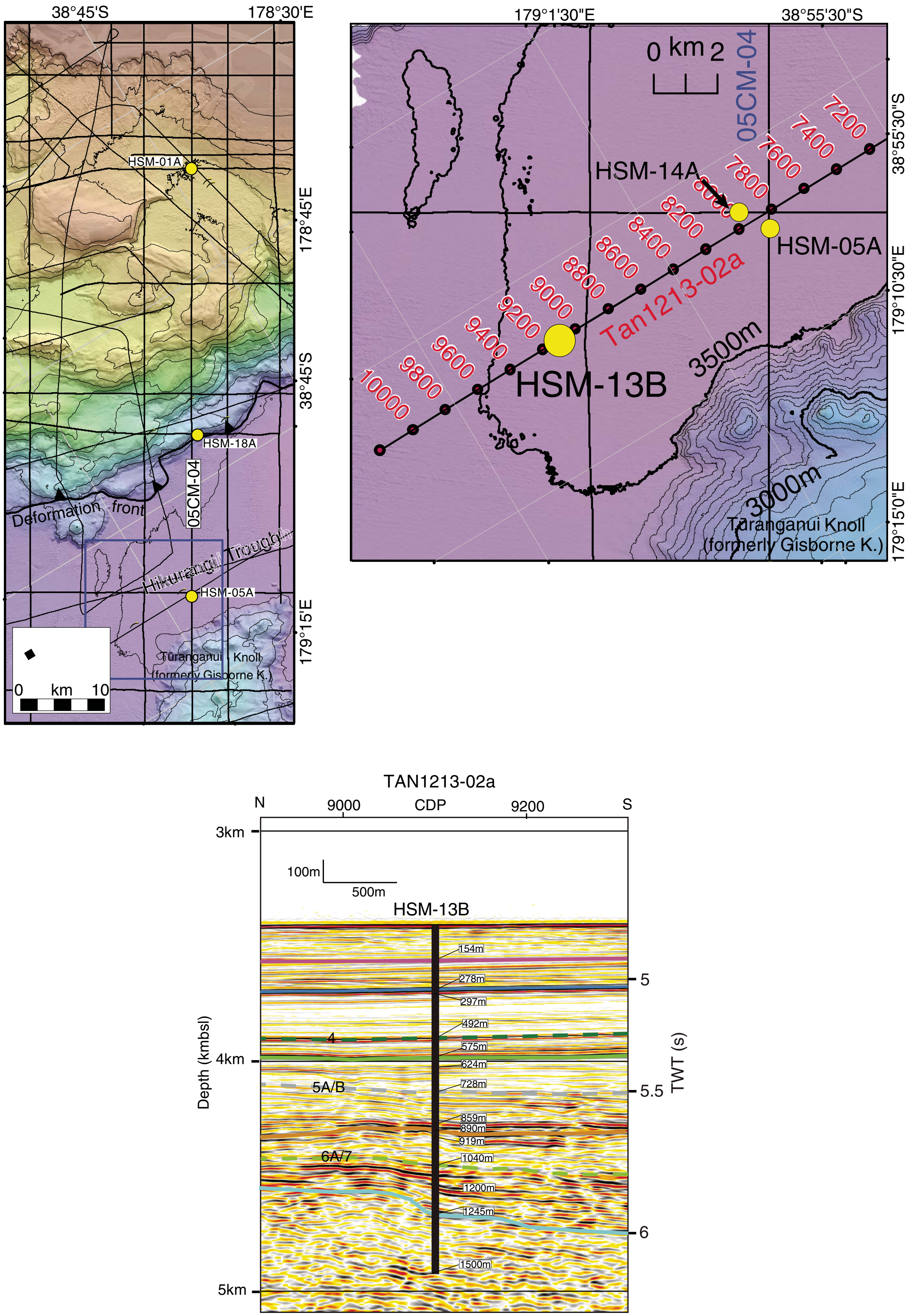


Figure AF19. Details of proposed alternate Site HSM-14A. A. Left: regional map of Expedition 372 subduction sites. Bold yellow dots = primary drilling sites, small dots = alternate sites. Note rotated north arrow. Right: enlarged bathymetry map showing drilling sites and contours (black) at 50 m intervals. Bottom: site position on seismic Section TAN1114-04.