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Toward Constraining the Paleoseismic History and Maximum Event Magnitude for the San Diego Trough Fault Zone

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Abstract:

Understanding offshore seismic hazard lags behind the understanding of onshore hazards because of the difficulty of imaging faults and sampling sediments underwater. Nevertheless, the potential hazard to coastal communities in Southern California from offshore faults is considerable, especially when these communities are located near long subduction zone or strike-slip plate boundary faults that have the potential to produce large earthquakes. The San Diego Trough fault offsets young sediments between the US/Mexico border and the eastern margin of Avalon Knoll, where the fault is spatially coincident with the mapped trace of the San Pedro Basin fault. *Ryan et al.* (2012) estimate a minimum Holocene slip rate of 1.5 ± 0.3 mm/yr for the San Diego Trough fault, however the paleoseismic history of the San Diego Trough fault is entirely unconstrained, forcing assumptions about potential earthquake magnitude, rupture lengths, and recurrence interval that increase uncertainty in seismic hazard models for Southern California.

Here, we present new seismic data to constrain the timing of the most recent event (MRE) on the San Diego Trough fault using new high-resolution chirp sub-bottom profiling and multichannel seismic reflection data in combination with coring studies. We surveyed the San Diego Trough fault at 3 different locations where the fault cuts young sediments dispersed through the Oceanside, Newport, and San Gabriel Canyon systems. Our preliminary results indicate that the fault has experienced multiple Holocene and latest Pleistocene earthquakes at the Oceanside Fan paleoseismic target. Upon the completion of sampling and radiocarbon analysis for the remaining core samples, we will use the chirp datasets in combination with age constraints from cores timing of the past earthquakes along central and southern stretches of the San Diego Trough fault. Constraining the timing of the MRE on different segments of the fault will allow us to begin constraining the extent and variability of past earthquake ruptures and improve estimates of the maximum event magnitude for the San Diego Trough fault.

1. Introduction

Understanding offshore seismic hazard lags behind the understanding of onshore hazards because of the difficulty of imaging faults and sampling sediments underwater. Nevertheless, the potential hazard to coastal communities in Southern California from offshore faults is considerable, especially when these communities are located near long subduction zone or strike-slip plate boundary faults that have the potential to produce large earthquakes. Uncertainties regarding basic seismic source parameters such as fault dip, length, mode of deformation, slip rate, and potential interactions between the offshore faults force assumptions about fault geometry, potential earthquake magnitude, rupture length, and recurrence interval that increase uncertainty in regional seismic hazard models.

Geodetic measurements show that the San Andreas fault and other fault systems onshore in Southern California accommodate ~85% of the 50 mm/yr total Pacific/North American relative right-lateral plate motion, leaving offshore faults in the Inner California Borderlands (ICB) to accommodate the remaining 15% of plate boundary deformation (e.g., *Bennett et al.*, 1996; *Dixon et al.*, 2000; *Meade and Hagar*, 2005; *Platt and Becker*, *2010*; *Hammond*, *2014*). Between the Southern California coast and San Clemente Island, 6-8 mm/yr of right lateral shear strain accumulates across a ~100 km-wide zone that spans the Newport-Inglewood/Rose Canyon, Coronado Bank, Palos Verdes, San Diego Trough, and San Clemente fault systems (Figure 1). These offshore northwest-striking, sub-parallel, strike-slip faults work together to release the accumulated shear strain (*Grant and Rockwell*, 2002), posing significant yet poorly understood seismic hazard for Southern California's densely populated coastal regions.

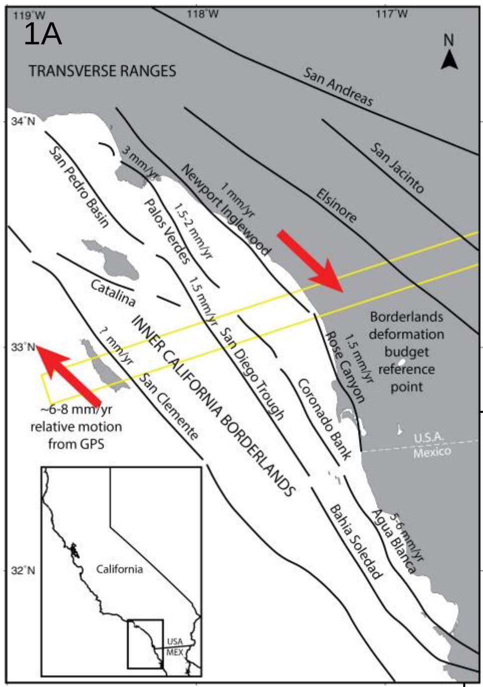
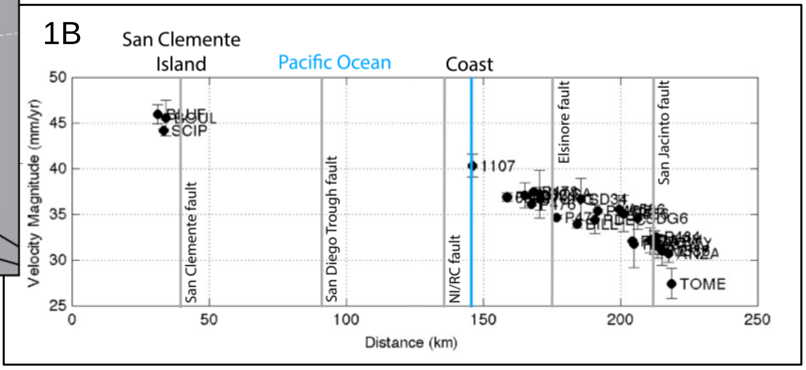


Figure 1. (A) Map of the Inner California Borderlands faults. Generalized fault traces and associated slip rates are labeled. Slip rates are from *Grant and Rockwell* (2002), with the exception of the San Diego Trough fault, (*Ryan et al*., 2012) and the Palos Verdes offshore estimate (*Brothers et al.*, 2015). Approximate sense of regional shear deformation is shown with red arrows. Figure modified from *Maloney et al*. (2016) after *Ryan et al.* (2012) and *Grant and Rockwell* (2002). **(B)** Profile showing the magnitude of GPS velocities with respect to stable North America (NA12 reference frame) for sites spanning the ICB and southern California. Location of profile is shown by yellow box in Figure 1A. Velocities from *Hammond* (2014).



The San Diego Trough fault lies directly west of the greater Los Angeles and San Diego metropolitan areas and extends 120 km from the U.S./Mexico Border to the eastern margin of Avalon Knoll (Figure 2). The fault has nearly continuous linear geomorphic expression as it offsets young sediments and landforms in the San Diego Trough and San Gabriel Canyon. The fault continues for ~100 km south of the border as the Bahia Soledad fault (e.g., *Legg et al.*, 1991; *Legg et al.*, 2007), resulting in a cumulative length of > 220km. Empirical magnitude-length scaling relationships indicate that an end-to-end rupture of the combined San Diego Trough/Bahia Soledad fault system could produce a M7.7 earthquake (*Wells and Coppersmith*, 1994). *Ryan et al.* (2012) estimate a minimum Holocene slip rate of 1.5 ± 0.3 mm/yr, and the length, linearity, and robust geomorphic expression of the San Diego Trough fault suggest that it is one of the most active faults in the Inner California Borderlands system.

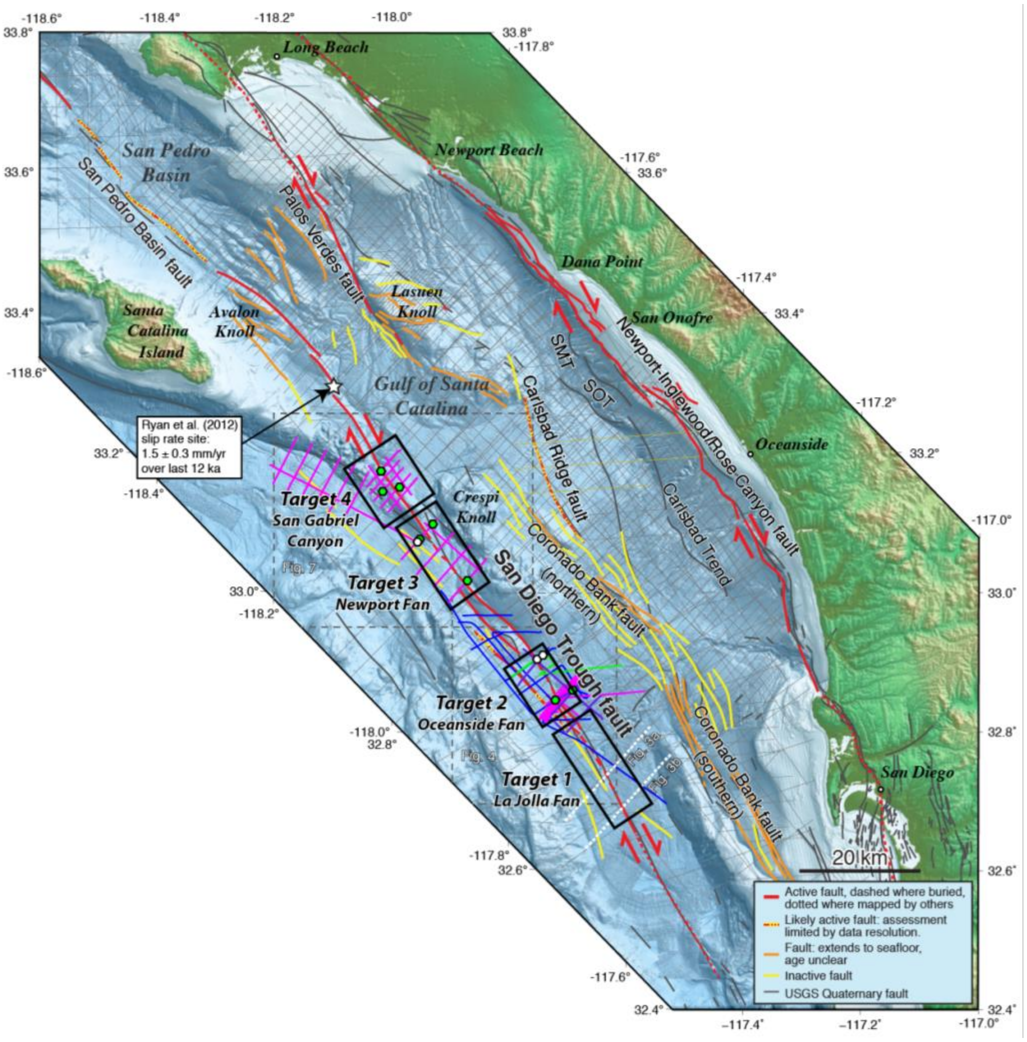


Figure 2. San Diego Trough fault survey map. Magenta grids denote the location of R/V Sally Ride chirp profiles. Green lines denote the location of the R/V Thompson chirp profiles, and blue lines denote the location of R/V Sikuliaq chirp profiles. Purple tracks mark the location of new sparker multichannel seismic reflection profiles acquired during this project. White hexagons mark the TN336 core locations, and green hexagons mark the SR1703 core locations. White dashed lines mark the locations of seismic profiles displayed in Figure 3, and grey dashed boxes mark the extent of the maps shown in Figures 4 and 7. Fault map modified from *Bormann et al*. (in review).

At present, the paleoseismic history of the fault is entirely unconstrained. This lack of knowledge necessitates many assumptions about earthquake magnitude and recurrence intervals that increase uncertainty in seismic hazard models. Our interpretation of regional 2D multichannel seismic reflection data (*Sliter et al*., 2005; *Kent and Driscoll*, 2013; *Driscoll et al.*, 2015a, 2015b; *Triezenberg et al.*, 2016) and regional multibeam bathymetry (*Dartnell et al.*, 2015) identified three locations where young deposits from the La Jolla, Oceanside, and Newport submarine fans appear to mantle the active trace of the San Diego Trough fault (Figure 2 – Targets 1, 2, and 3, respectively). These targets provide an ideal sedimentary record to constrain the timing of the MRE along the central and southern stretches of the San Diego Trough fault.

The goal of this project was to determine the timing of the most recent event (MRE) at different locations along the central and southern sections San Diego Trough fault using high-resolution CHIRP and multichannel seismic reflection sub-bottom profiles, multibeam bathymetry, and coring studies. Here, we present new observations from on-going submarine paleoseismic investigations. This report describes the results of these efforts with maps, interpreted seismic reflection profiles, and core logs. Constraining the timing of the MRE on different segments of the fault is the first step toward improving estimates of the recurrence interval, extent and variability of past ruptures, and maximum event magnitude for the San Diego Trough fault.

2. Seismic Data

Our planned approach for this project was to acquire chirp sub-bottom profiles using the Scripps Institution of Oceanography (SIO)/University of California San Diego custom built Subscan Chirp aboard the 32’ R/V Point Loma for oceanographic surveying during the summer of 2016. Although this instrument has previously been successful in acquiring data at water depths of over 1250 m in southern San Diego Trough aboard the R/V Sproul, the noise from the outboard engines on the R/V Point Loma overpowered the chirp signal and the instrument was unable to identify and record the reflected pulses. To compensate for this unexpected equipment limitation, we leveraged ship time during coring shake-down cruises on the R/V Sally Ride in 2017 to run seismic surveys across the San Diego Trough fault using the hull-mounted Knudsen sub-bottom profiler. We combine these data with sub-bottom profiles collected during coring cruises aboard the R/V Thomas G. Thompson and R/V Sikuliak during 2016. During the spring of 2018, we used our remaining ship time and survey funds to mobilize California State University Long Beach’s multichannel seismic reflection system and acquire sparker seismic data along the San Diego Trough fault. In total, this project resulted in 465 line-km of new high-res seismic data that image recent deformation at our survey targets along the central and southern San Diego Trough fault (Figure 2). The details of the chirp and sparker surveys are described in the following sections.

2.1 Single-Channel Sub-bottom Profiling

The primary chirp survey for this project was conducted during a coring shake down cruise on the R/V Sally Ride under Captain Ian Lawrence between February 3-11th, 2017. Chief Scientist Mitch Lyle graciously allowed us to run seismic profiles overnight between coring operations. The surveys were conducted by Hector Perea and Neal Driscoll (SIO), with

Bormann (UNR/CSULB) remotely planning and monitoring data collection from shore. This survey resulted in 32 new profiles totaling 280 line-km of ultrahigh resolution sub-bottom profiles (Figure 2 - magenta grid). The data were acquired using the hull-mounted Knudsen Chirp 3260 Echosounder operated at 3.5 khz. The survey speed ranged between 4.0-5.5 knots with a 3-second shot interval. The reflected waveforms were sampled at 0.06 ms intervals for a 0.267 second window that auto-tracked the seafloor. The signal penetrated between 0.6-1 seconds of two-way-travel-time beneath the seafloor, imaging reflectors in the upper 45-70 m of sediment (all sub-bottom depths and stratal thicknesses estimated assuming a sound velocity of 1500 m/s).

Supplementary chirp profiles were collected using the hull-mounted echosounders on the R/V Thomas G. Thompson and R/V Sikuliaq during coring cruises in early 2016. The Thompson profiles were collected using a Knudsen 320 BR echosounder, and the Sikuliaq profiles were collected using a Kongsberg Topas PS18 parasound sub-bottom profiler. Five profiles were collected aboard the Thompson, totaling 25 line-km of new data (Figure 2 – green grid). The R/V Sikuliaq is designed as an ice-capable polar research vessel, and accordingly, it has a broad and relatively flat-bottomed design. The profiles acquired aboard the Sikuliaq were collected during a science operations shakedown cruise in moderate swell conditions. Due to the flat-bottomed design of the ship, the ship has a tendency to list to leeward in windy conditions. The combination of listing and moderate swell significantly reduced the reflected signal strength recorded by the sub-bottom profiler transducers due to cavitation bubbles at certain headings. In total, 13 out of 40 recorded profiles aboard the Sikuliaq are interpretable, resulting in 110 line-km of new seismic data (Figure 2 – blue grid). The data quality, ship speed, and recording parameters in these surveys are variable. Accordingly, we use these profiles only as a supporting dataset in this work.

2.2 Sparker Multichannel Seismic Reflection

The multichannel seismic reflection survey was conducted on the R/V Point Loma under Captain Neal Driscoll during agreeable weekend weather windows in April 2018. The science party consisted of PIs Bormann (UNR/CSULB) and Kent (UNR), and Scripps Institution of Oceanography postdoc Hector Perea and students Boe Derosier, Colby Nicholson, and Daniel Schwartz. The survey was conducted over three single-day trips, with the vessel departing and returning to San Diego daily. We collected six new profiles totaling 50 line-km of high-resolution multichannel seismic reflection data (Figure 2 – purple grid). The data were acquired using California State University's 16-channel digital Geo-Eel hydrophone streamer with 6.25 m group spacing and a 2-kJ three-tip sparker energy source. Both the source and the streamer were towed at 3 m depth, with a near offset of 25 m. The survey speed ranged between 4.0-4.2 knots in favorable weather conditions with swells of less than 1m. The shot interval was 3 seconds, resulting in a nominal common mid-point spacing of 3.125 m. The reflected waveforms were sampled at 0.5 ms intervals for 2.5 seconds to image roughly twice the maximum seafloor depth.

We processed the data using a combination of Matlab and Sioseis (*Henkart*, 2003). The processing workflow consisted of (1) assigning source and receiver geometry to the shot records, (2) trace editing, (3) sorting the shot gathers to create CMP gathers, (4) minimum-phase bandpass filtering (5) applying a normal moveout correction, (6) stacking the CMP gathers into single CMP traces, and (7) frequency-wave number (f-k) migration. All processing and travel-time to depth conversions in this paper assume water column and sediment velocities of 1500 m/s. The processed data contain acoustic frequencies between 20-200 Hz, resulting in a vertical resolution of ~3-5 m with maximum penetration over 1000 ms (~750 m) beneath the seafloor.

3. Coring Studies

The seismic data acquired in this project are complementary to sediment cores recently collected along San Diego Trough fault to provide age constraints for the faulted sedimentary horizons. The cores were collected on two cruises: TN336 aboard the R/V Thomas G. Thompson in January 2016 and SR1703 aboard the R/V Sally Ride in February 2017. Three cores from the San Diego Trough were collected on the TN336 cruise, and nine additional cores from were collected as part of SR1703 cruise (Figure 2 – white and green hexagons, respectively). Eleven of the cores are jumbo piston cores (JPC) that range between 2.5-5.3 m in length, and there is one 1.4 m gravity core. Core collection dates, sample locations, core type, and length are listed in Table 1.

Table 1. Core Sample Locations and Basic Metrics

Cruise	Core #	Core Type	Latitude (° N)	Longitude (° W)	Water Depth (m)	Core Length (cm)	Trigger Core Length (cm)
TN336	11-11	JPC	33.0715	-117.9539	951	254	201
TN336	49-60	JPC	32.9033	-117.7503	1044	264	123
TN336	50-61	JPC	32.9092	-117.7405	1028	290	138
SR1703	02-02	JPC	32.8588	-117.6898	1033	411	174
SR1703	03-03	JPC	33.1501	-117.9845	862	375	84
SR1703	04-04	JPC	33.1438	-118.0131	942	504	175
SR1703	05-05	JPC	33.1729	-118.0161	940	486	183
SR1703	05-06	JPC	33.1729	-118.0161	940	532	170
SR1703	08-15	JPC	33.0972	-117.9277	906	319	125
SR1703	09-16	JPC	33.0755	-117.9502	949	504	166
SR1703	10-17	JPC	33.0160	-117.8691	919	513	192
SR1703	11-19	Gravity	32.8447	-117.7194	1069	142	N/A

The TN336 cores were collected, described, scanned, sampled, and dated as part of a larger study looking at patterns of sediment delivery to the Inner California Borderlands from the Last Glacial Maximum to present (*Wei et al*., 2018). In this work, a total of 110 samples from 90 unique locations and depths were collected for radiocarbon dating, preferentially from planktonic foraminifera. For 20 samples, both planktonic and benthic samples were collected in order to determine a reservoir age. The samples were analyzed at The National Ocean Sciences Accelerator Mass Spectrometry facility at the Woods Hole Oceanographic Institution and produced an age using the Libby half-life of 5568 years and following the convention of *Stuiver and Polach* (1977). The ^{14}C ages were converted to calendar years using the CALIB program version 7.0.4 (*Stuiver and Reimer*, 2014) with a reservoir age of 800 yr for planktonic foraminifera <12,000 yr and a reservoir age of 1100 yr for planktonic foraminifera >12,000 yr (*Southon et al.*, 1990; *Kienast and McKay*, 2001; *Kovanen and Easterbrook*, 2002). From the 20 samples that dated both benthic and planktonic foraminifera, an average residual difference in reservoir age of 900 years was calculated. Therefore, for benthic foraminifera <12,000 yr, a reservoir age correction of 1700 yr has been applied, and for benthic foraminifera >12,000 yr, a reservoir age correction of 2000 yr has been applied. These corrections are comparable to the reservoir age of 1750 for benthic foraminifera used by *Mix et al.* (1999) and *Covault et al*. (2010). The SR1703 cores are currently being described, sampled, and processed for radiocarbon analysis. The calibrated ages and seismic data are used to determine the paleoseismic history of the San Diego Trough fault.

Table 2. Radiocarbon Dated Samples From Sediment Cores

Core ID	Sample Number	Depth Below Seafloor (cm)	Sample Type	^{14}C Age (yr B.P.)	Age Error (± yr)	Calendar Age (cal yr B.P.)
TN336 JPC 11-11	11_11_148b	148-151	mixed benthic foraminifera	9,280	30	8,451
TN336 JPC 11-11	11_11_165b	165-169	mixed benthic foraminifera	13,550	45	13,409
TN336 JPC 11-11	11_11_189p	189-192	mixed planktic foraminifera	13,050	45	13,825
TN336 JPC 11-11	11_11_189b	189-192	mixed benthic foraminifera	14,000	55	13,890
TN336 JPC 11-11	11_11_231b	231-235	mixed benthic foraminifera	19,350	85	20,939
TN336 JPC 49-60	49_60_123p	123-127	mixed planktic foraminifera	9,090	30	9,368
TN336 JPC 49-60	49_60_123b	123-127	mixed benthic foraminifera	9,940	35	9,315
TN336 JPC 49-60	49_60_141p	141-144	mixed planktic foraminifera	9,460	30	9,784
TN336 JPC 49-60	49_60_159p	159-162	mixed planktic foraminifera	9,960	30	10,436
TN336 JPC 49-60	49_60_171p	171-175	mixed planktic foraminifera	10,100	30	10,611
TN336 JPC 49-60	49_60_248b	248-252	mixed benthic foraminifera	13,550	40	13,408
TN336 JPC 49-60	49_60_248p	248-252	mixed planktic foraminifera	12,550	40	13,318

4. New Observations and Preliminary Results

Mapping by *Ryan et al.* (2012) and *Bormann et al.* (in review) has refined the geometry of the San Diego Trough fault trace and identified stepovers and geometrical complexities along the fault that could act as segment boundaries with the potential to arrest ruptures. In preparation for this project, we selected three locations where young deposits from submarine fans are cut the active trace of the San Diego Trough fault near the La Jolla, Oceanside, and Newport Canyon submarine fans (Figure 2 – Targets 1, 2, and 3). These locations provide an ideal sedimentary tape recorder to constrain the timing of the MRE along the central and southern stretches of the San Diego Trough fault.

4.1 Survey Target 1 – La Jolla Fan

The La Jolla Fan target initially seemed to be one of the most promising sites due to the clear stratigraphic relationship between the fault and the overlying fan deposits in sparker seismic profiles (Figure 3). Unfortunately, we were forced to abandon this potential paleoseismic site early in the project as the entire target lies within an explosives dumping ground (*NOAA*, 2010). This precluded our ability to collect core samples for age control within the target, and we chose to focus our efforts on paleoseismic targets to the north.

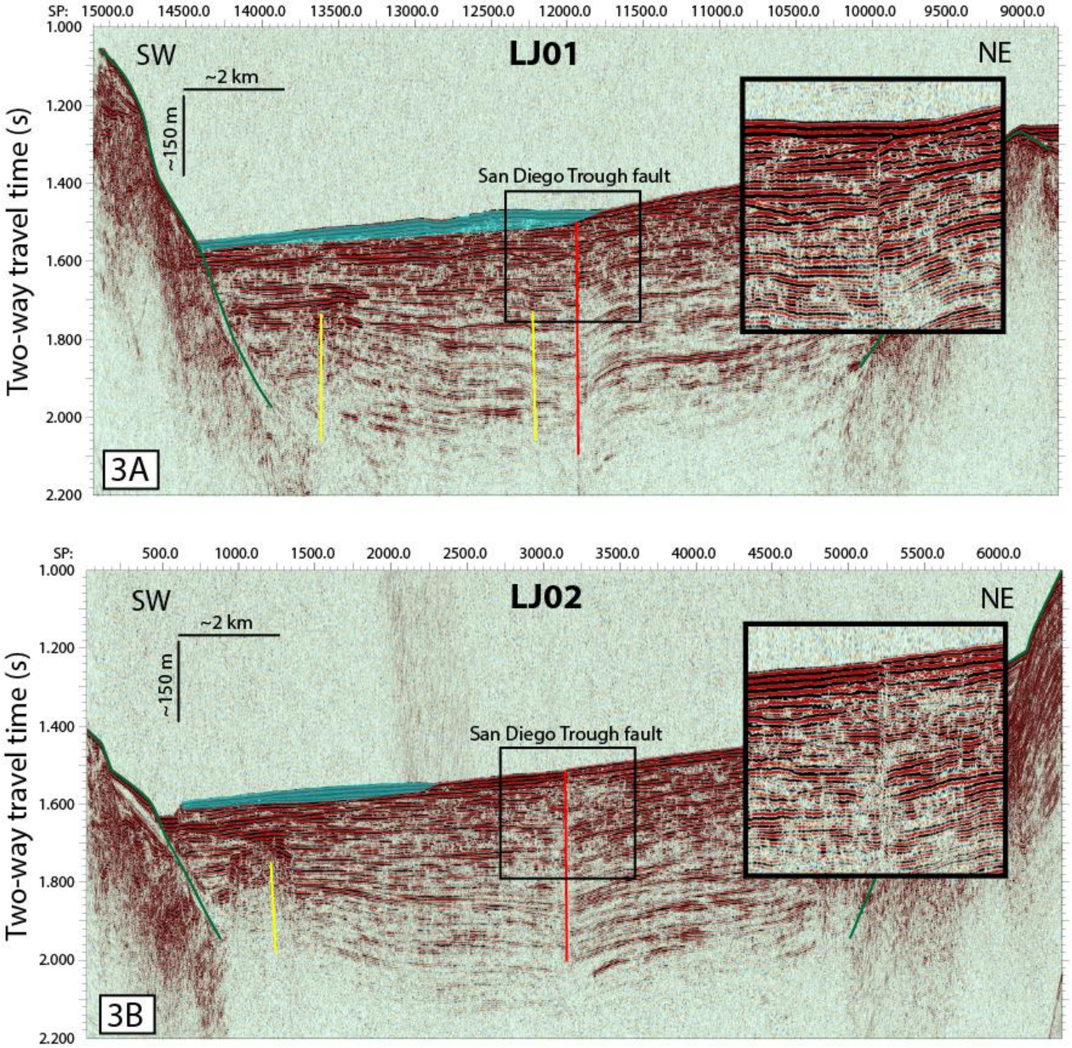


Figure 3. Interpreted high-resolution MCS sparker reflection profiles (*Driscoll et al.*, 2015a) crossing the San Diego Trough fault (red lines) and other inactive faults (yellow lines) in Target 1. Location of profiles shown in Figure 2. Inset shows an enlargement of deformation associated with the fault. Blue polygon highlights the young overbank deposits from the La Jolla submarine fan. Interpreted basement shown in green. (A) Profile LJ01, sediments cut by the San Diego Trough fault are overlain by undeformed channel overbank deposits. (B) Profile LJ02, the San Diego Trough fault clearly offsets young sediments in the San Diego Trough and the seafloor.

4.2 Survey Target 2 – Oceanside Fan

The Oceanside Fan site occurs where sediment transported through Oceanside Canyon is deposited in a submarine fan as the canyon widens and becomes unconfined as it enters San Diego Trough along the southern margin of the Crespi Knoll uplift. These sediments mantle and are cut by the San Diego Trough fault. At this location, the main (eastern) strain of the San Diego Trough forms the eastern boundary of the San Diego Trough. In the northern end of the target region, slip from the fault appears to stepover to a secondary fault strand located approximately 3 km to the west of the main strand. The subsurface sediments in this region have been imaged with chirp and sparker MCS seismic reflection profiles and sampled during the TN336 and SR1703 cruises.

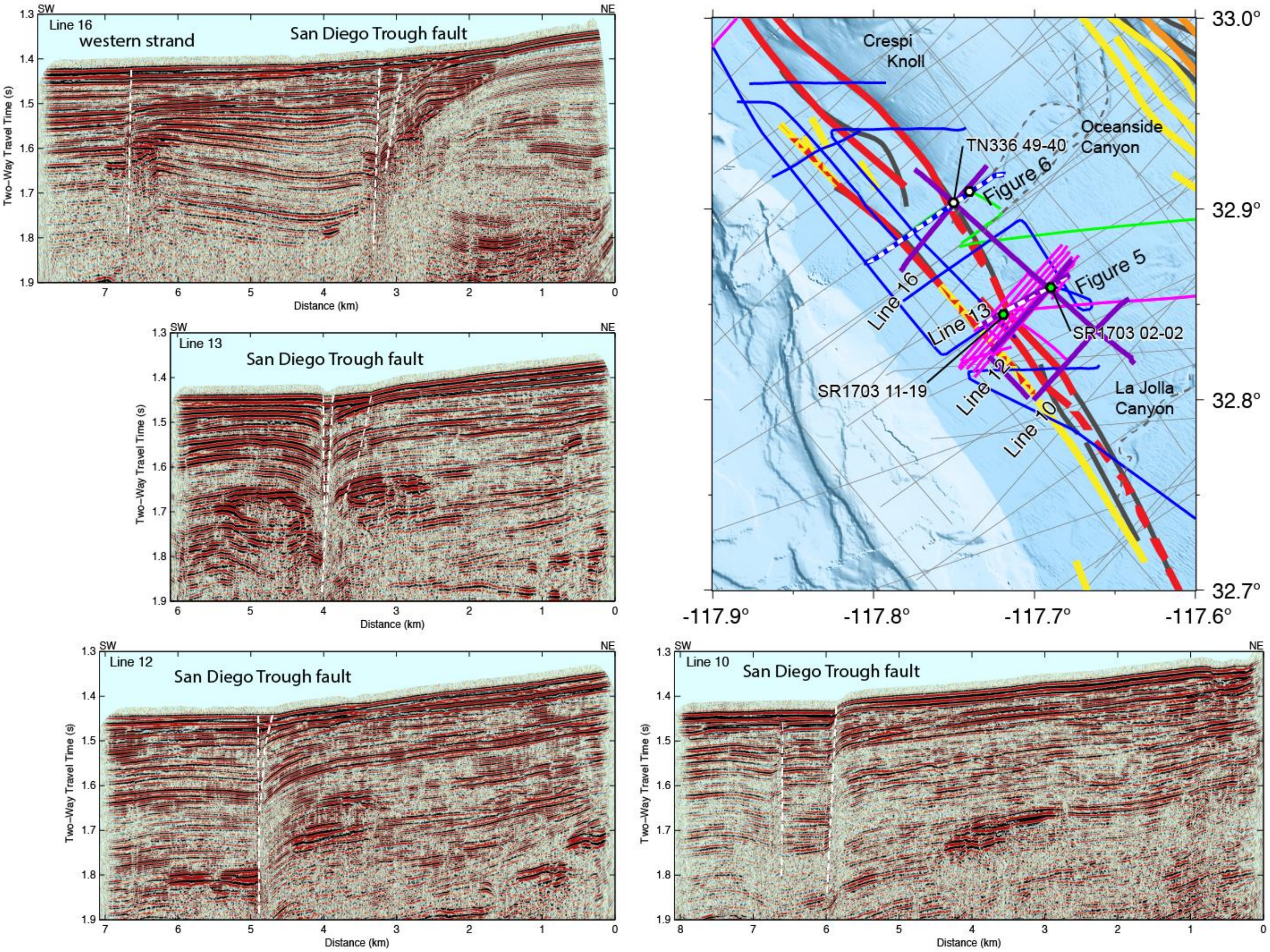


Figure 4. New sparker MCS profiles imaging the San Diego Trough fault near the Oceanside fan paleoseismic target. Sparker profile locations marked by labeled purple lines on the basemap. Magenta lines denote the location of R/V Sally Ride chirp profiles. Green lines denote the location of the R/V Thompson chirp profiles, and blue lines denote the location of R/V Sikuliaq chirp profiles. White hexagons mark the TN336 core locations, and green hexagons mark the SR1703 core locations. White dashed lines mark the location of chirp profiles shown in Figures 5 and 6. Fault colors distinguish recency of activity as distinguished in Figure 2. Gray dashed lines mark the location of the active Oceanside and La Jolla Canyons.

Figure 4 shows the results from 4 new sparker seismic reflection profiles acquired over the Oceanside Fan target. Due to the low (8) fold of the data, most reflected energy is concentrated in the upper 300-500 m of sediment. We limit our interpretations to this region. The primary eastern fault strand is imaged in all profiles. In the southernmost profile located between the La Jolla and Oceanside fans, Profile 10, the fault is expressed by an ~10 m down to the west scarp. A secondary fault strand located ~0.5 km to the west appears to buried by young sediment spilling northward from La Jolla Canyon. Moving 4 km to the north, Profiles 12 and 13 image the San Diego Trough fault forming a 150-m-wide graben along the eastern margin of the trough. At the northern end of the Oceanside Fan target, Profile 16 images two strands of the San Diego Trough fault. The eastern strand, which has been the primary fault strand to the south, appears to be buried by a highly reflective lens of sediment. In contrast to the southern profiles, Profile 16 images the western strand of the San Diego Trough fault offsetting surface reflectors. Crespi Knoll is recognized as a compressional left-step in the San Diego Trough fault system (*Ryan et al.*, 2012; *Maloney et al.*, 2015), and the westward step in surface faulting is likely a result of the fault reorganization around the restraining bend.

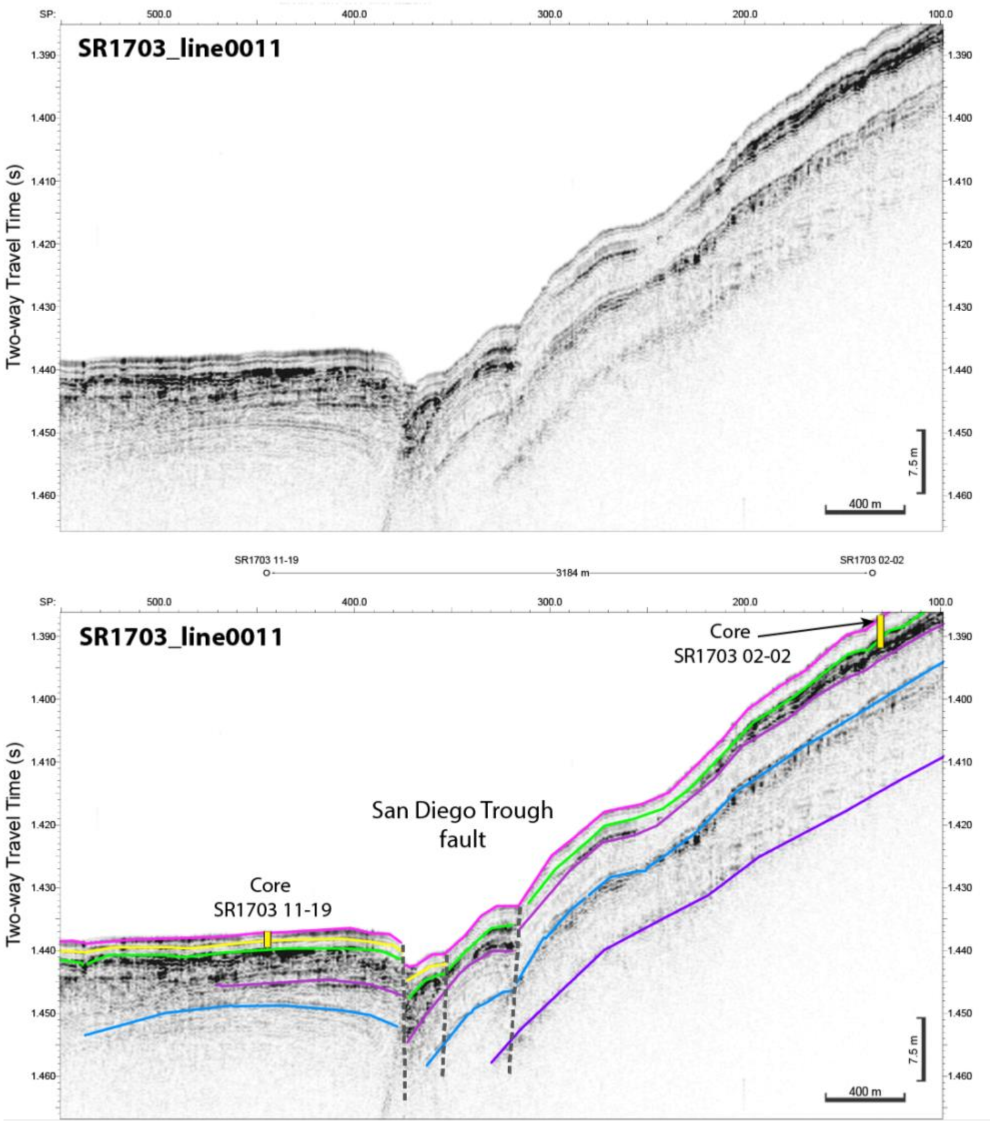


Figure 5. Chirp profile SR1703_line0011 imaging Holocene and latest Pleistocene strata offset by the San Diego Trough fault. Yellow lines mark the locations of cores SR1703 02-02 and SR1703 11-19. Pink, yellow, and green horizons are regionally prevalent Holocene age reflectors correlated with sandy layers in core TN336 49-60 and high-amplitude reflectors in chirp line SKQ_20160310021947_007b (Figure 6). Profile location marked in Figure 4.

The graben imaged in Profile 13 preserves the clearest and most complete record of paleoseismic deformation and Holocene and latest Pleistocene sedimentation in this section of the fault. We collected a detailed chirp grid over this region to elucidate the stratigraphic details (Figure 4, magenta grid). Chirp profile SR1703_line0011, collocated with sparker profile 13, images the uppermost 15-20 m of sediment in this region (Figure 5). The uppermost sedimentary package is an acoustically transparent layer with a thickness of ~3 m. To the west of the fault within the San Diego Trough, 3 regionally continuous high-amplitude reflectors punctuate this layer (magenta, yellow, and green reflectors in Figures 5 and 6). Although the cores near SR1703_line0011 have not yet been dated, we use an initial age correlation from core TN336 49-60 (Figure 6) to infer that the acoustically transparent layer represents Holocene hemipelagic clay/slit drape with thin coarser silt and sand turbidite layers creating the high-amplitude reflectors. A high-amplitude package underlies the hemipelagic drape (between green and purple horizons). This package thickens and the reflectors become discontinuous within the graben and to the west of the fault. An acoustically transparent layer underlies the high-amplitude package, and this layer is underlain by low-amplitude locally continuous reflectors. Sediments in the profile are cut by three stands of the San Diego Trough. The packages thicken and dip to the west within the graben demonstrating growth stratigraphy. Deeper horizons are progressive offset by larger distances along the western graben fault, indicating that this section of the fault has experienced multiple latest Pleistocene and Holocene earthquakes.

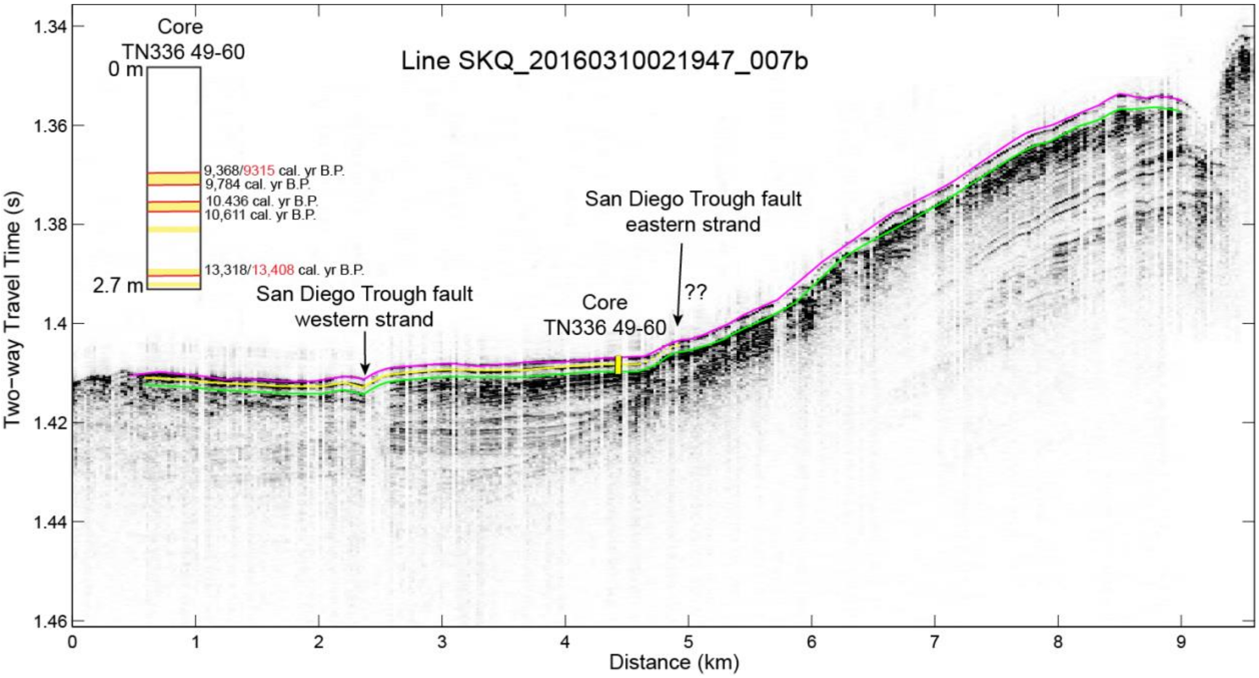


Figure 6. Correlation between dated sedimentary layers in core TN336 49-60 and reflectors in chirp line SKQ_20160310021947_007b. Inset graphic shows the stratigraphic position and ages of dated samples within the core. Core sedimentology is generalized with white regions representing fine-grained hemipelagic muds and yellow regions representing coarser-grained turbidite deposits. Red lines mark regions for radiocarbon analysis. A yellow line marks the location of core TN336 49-60 along the profile. Pink, yellow, and green horizons are regionally prevalent Holocene age reflectors correlated with sandy layers in core TN336 49-60 and high-amplitude reflectors in chirp line SR1703_line0011 (Figure 5). Profile location marked in Figure 4.

4.3 Survey Target 3 – Newport Fan

The Newport Fan site occurs where sediment transported through Newport Canyon is deposited in a submarine fan as the canyon enters the northern end of the San Diego Trough after winding around the northwestern margin of the Crespi Knoll. The canyon is confined between the west side of Crespi Knoll and the eastern margin of the dissected bedrock high. As the canyon enters the San Diego Trough and becomes unconfined, it has deposited a broad fan composed of highly reflective sediments to the west of the fault. The subsurface sediments in this region have been imaged with chirp seismic reflection profiles and sampled during the TN336 and SR1703 cruises. Multiple fault segments enter the Newport Fan region from the south, however only one segment is clearly imaged in seismic reflection profiles and multibeam bathymetry north of the fan (Figure 7). The structural relationships between fault strands in the southern part of the target and the northern part of the target are difficult to define because of the shallow signal penetration and chaotic nature of the reflectors in the central portion of the fan.

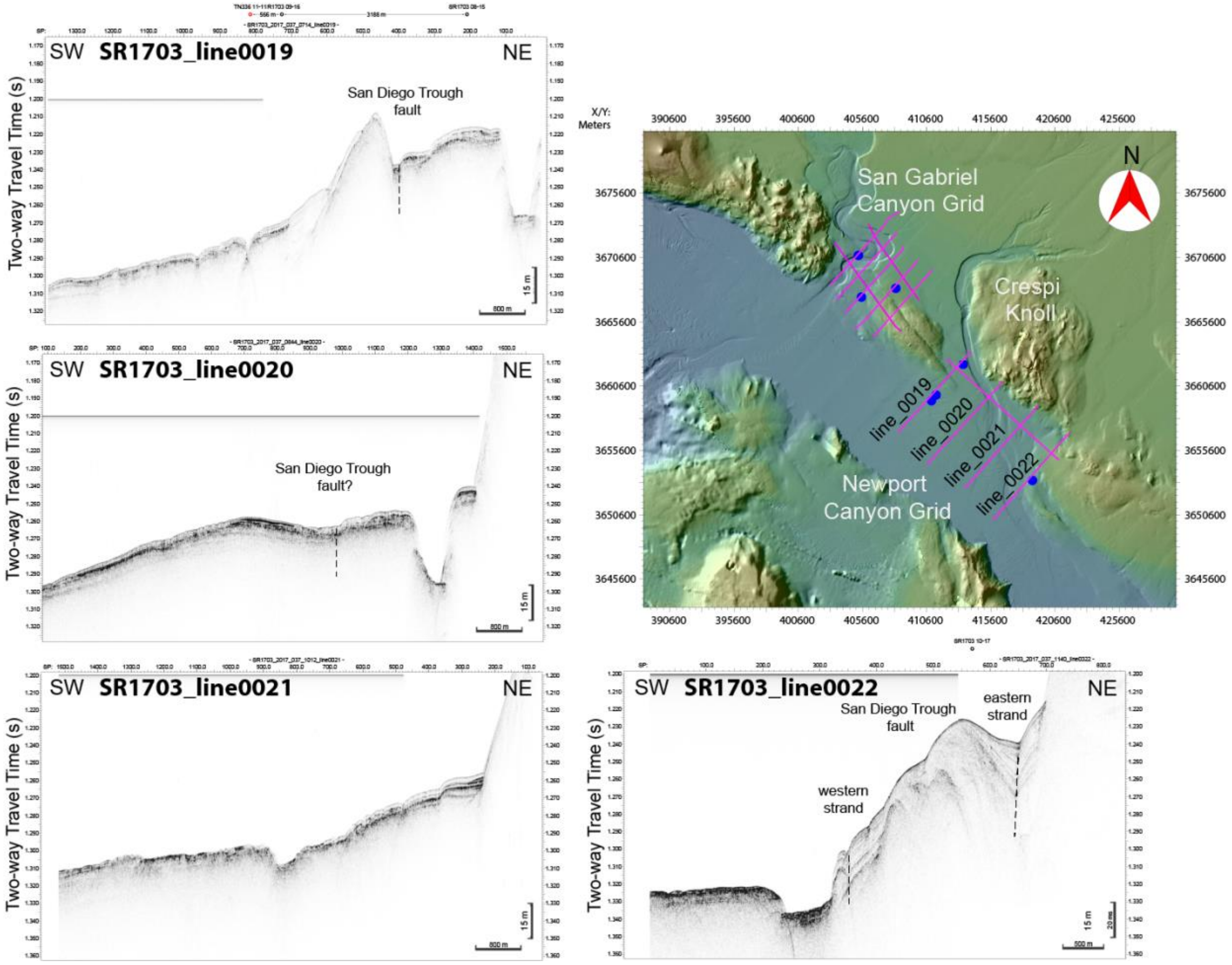


Figure 7. Chirp sub-bottom seismic reflection profiles from the Newport Canyon paleoseismic target. Seismic profile locations from the SR1703 cruise and core sites (magenta lines and blue circles, respectively) are shown for the Newport Fan and San Gabriel Canyon paleoseismic targets.

4.4 Survey Target 4 – San Gabriel Canyon

In addition to acquiring seismic data in the San Diego Trough, we also acquired chirp data and cores where the San Diego Trough faults interests the San Gabriel Channel to the southeast of Catalina Island. At this location, the fault right-laterally offsets a series of benches within in the canyon, with higher (older) benches progressively offset by greater amounts than lower (younger) benches. Relative age is inferred from the bench height above the channel thawleg. Although this site was not part of our original project plan, we chose to focus part of our efforts here because of the potential to constrain both the paleoseismic history and longer-term slip rate of the fault. Seven chirp profiles and four cores were acquired at this location during the R/V Sally Ride SR1703 cruise (Figures 2 and 7).

5. Broader Impacts and Dissemination

This project supported research costs and salary for an early career postdoctoral researcher and new faculty member (PI Bormann). Results from this work have been presented at the 2018 Seismological Society of America Meeting and will be submitted for publication to the Bulletin of the Seismological Society of America of similar journal pending results from radiocarbon analysis of sediment cores.

6. Seismic Data Archival (updated October 2021)

Seismic data collected for this project are collectively archived in the Harvard Dataverse in the San Diego Trough fault marine seismic dataverse (https://dataverse.harvard.edu/dataverse/SDTF_seismic). Individual datasets housed within the dataverse, including segy files, navigation data, line plots, and metadata from each survey are archived at the links below:

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Bormann, Jayne, 2021, "TN336 Knudsen singlebeam echosounder data", https://doi.org/10.7910/DVN/VLPJF3, Harvard Dataverse, V1

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