KECK REALTIME SEISMIC/GEODETIC BOREHOLE STATION

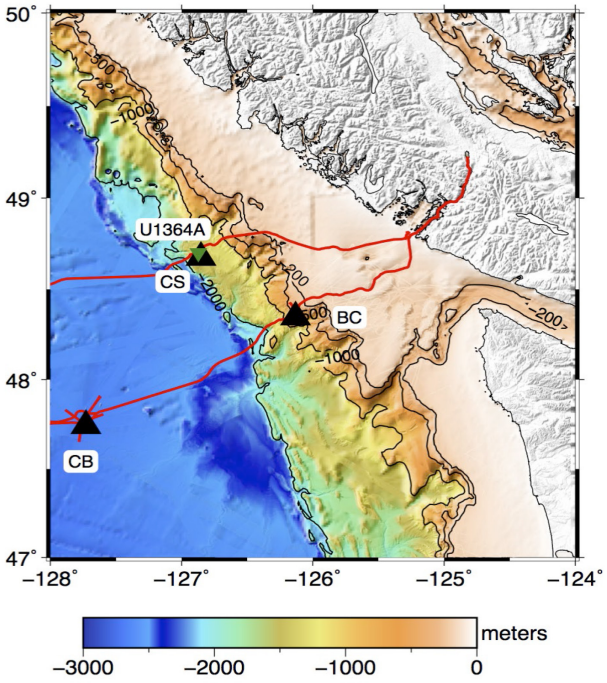
WHOI Ocean Bottom Seismograph Laboratory

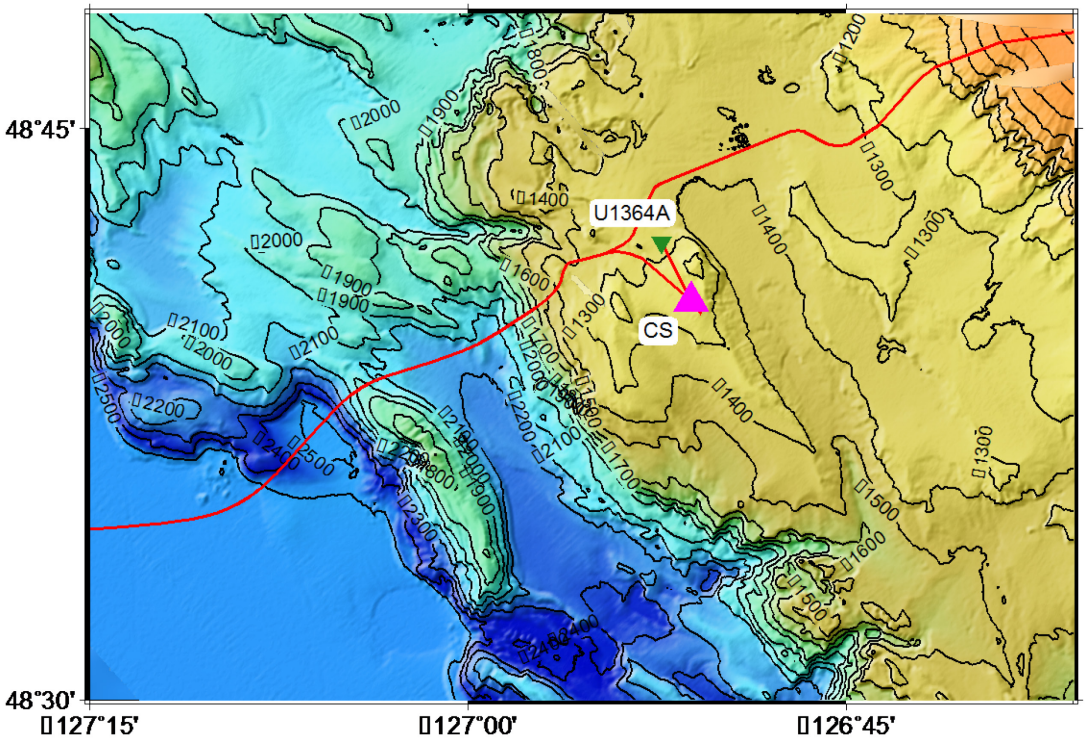
W.M. Keck Foundation Award to Design and Construct a Real-Time Borehole Seismic and Geodetic Observatory for Deployment Above the Cascadia Subduction Zone

In 2012, the *W.M. Keck Foundation* awarded funding to Jeff McGuire and John Collins to design and build a seafloor geodesy observatory for deployment above the rupture zone of the next M9 Cascadia earthquake.

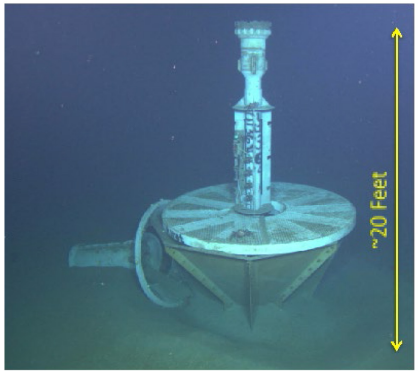
In July 2016, using NSF funding, the WHOI Jason ROV installed a suite of geodetic, seismic, and geothermal (provided by Keir Becker, RSMAS) sensors in IODP borehole U1364A on the Cascadia Accretionary Prism offshore Vancouver Island. The borehole observatory was connected to the Clayoquot Slope node of the Ocean Networks Canada (ONC) NEPTUNE Observatory in June 2017. The 3 km long extension cable provides power, timing, and internet connectivity. The borehole sits ~4 km above the subduction zone thrust interface, and when drilled in 2010 was instrumented with an ACORK (Advanced Circulation Obviation Retrofit Kit) that allows monitoring and sampling of fluids from multiple zones within the ~330 m drilled formation. The combination of geodetic, seismic sensors, geothermal, and ACORK sensors will allow understanding of the relationship between fluid pressures, temperatures, and deformation transients near the up-dip edge of the Cascadia subduction zone.

Location



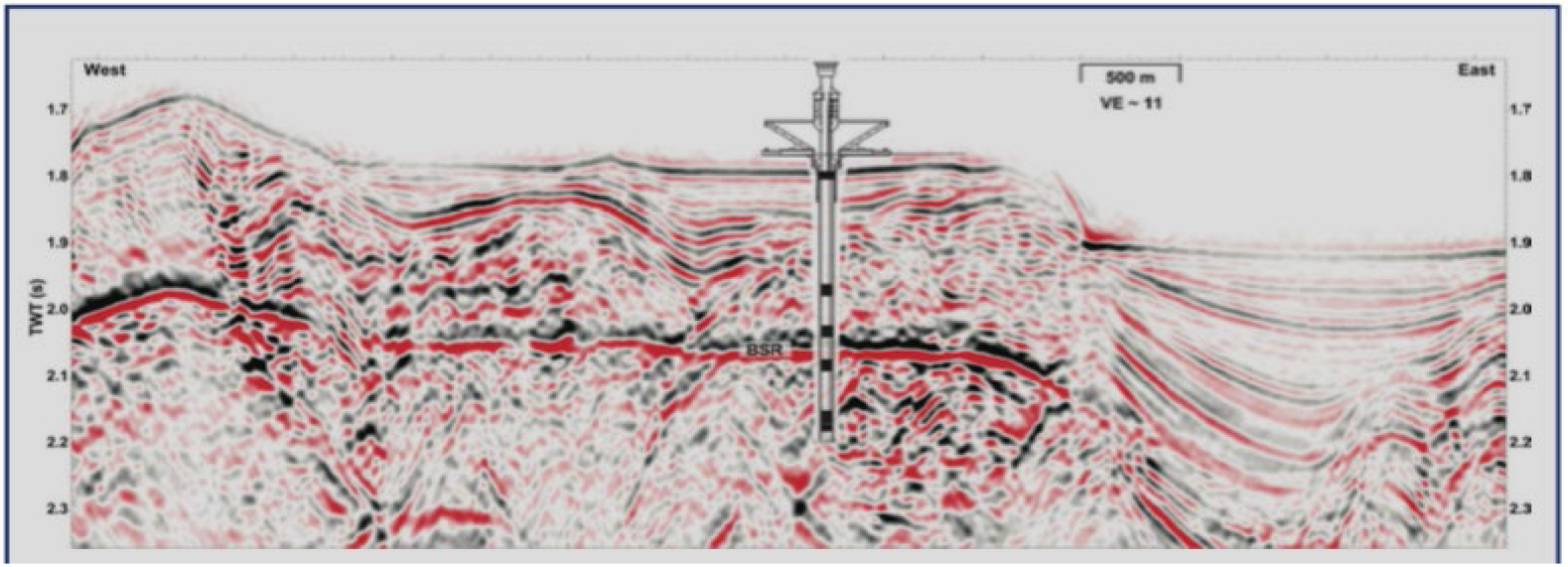


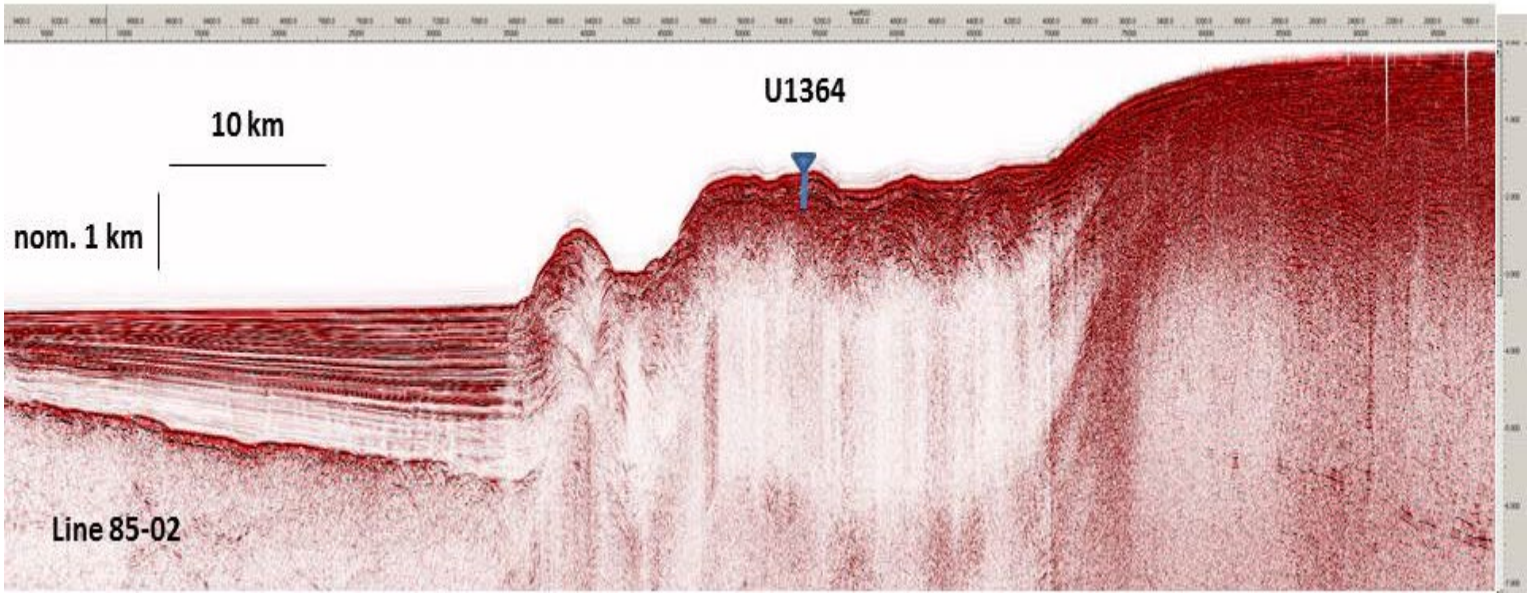
Location of IODP Hole U1364A (green triangle), relative to the Ocean Neworks Canada (ONC) seafloor cable nodes at Clayoquot Slope (CS), Barclay Canyon (BC) and Cascadia Basin (CB). Hole U1364A is ~3 km from ONC's Clayoquot Slope node. The red line shows the NEPTUNE cable route.

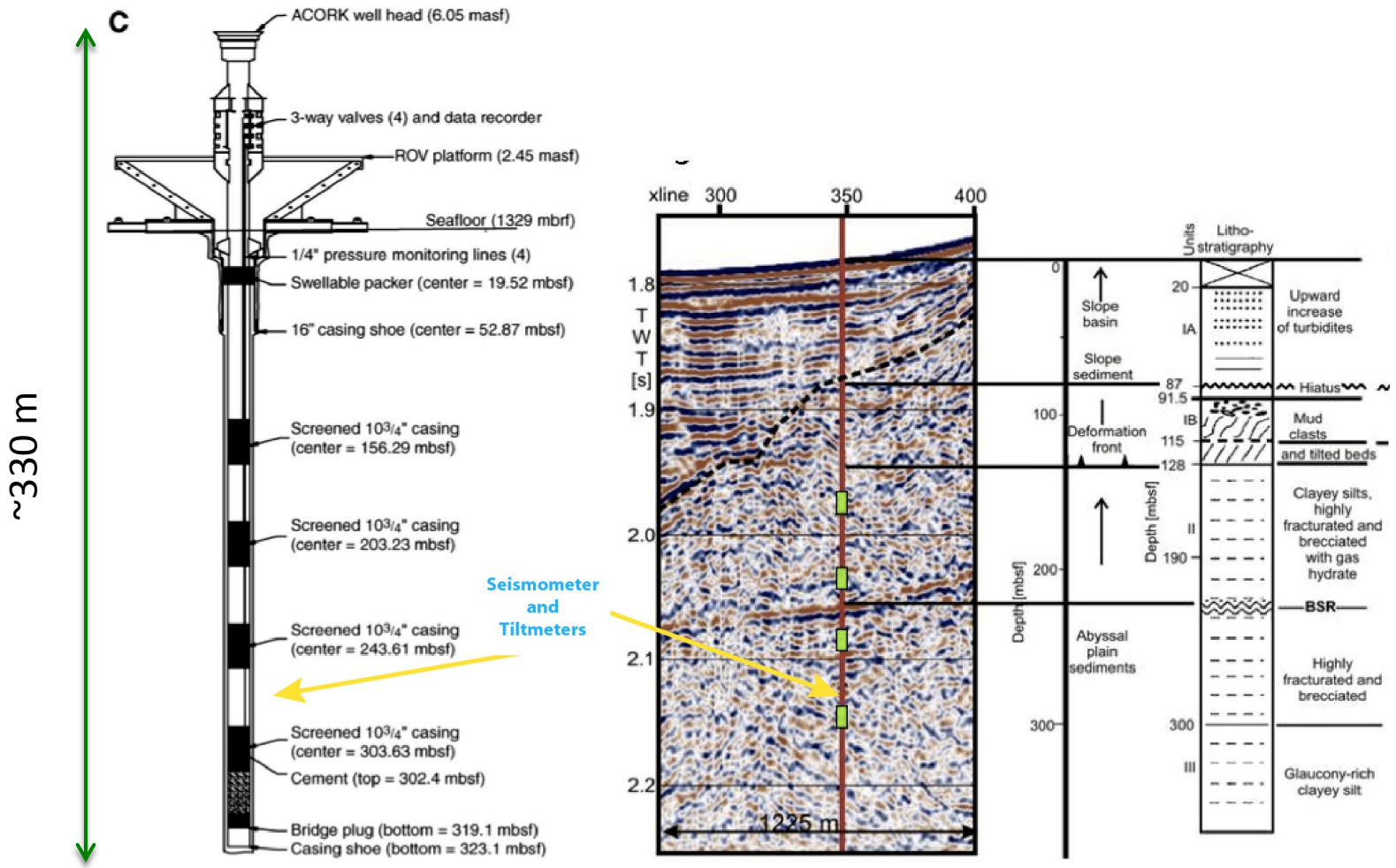


View of the seafloor component of the ACORK (Advanced Circulation Obviation Retrofit Kit) installed at Hole U1364A in 2010.

Cross Sections Through IODP Site U1364







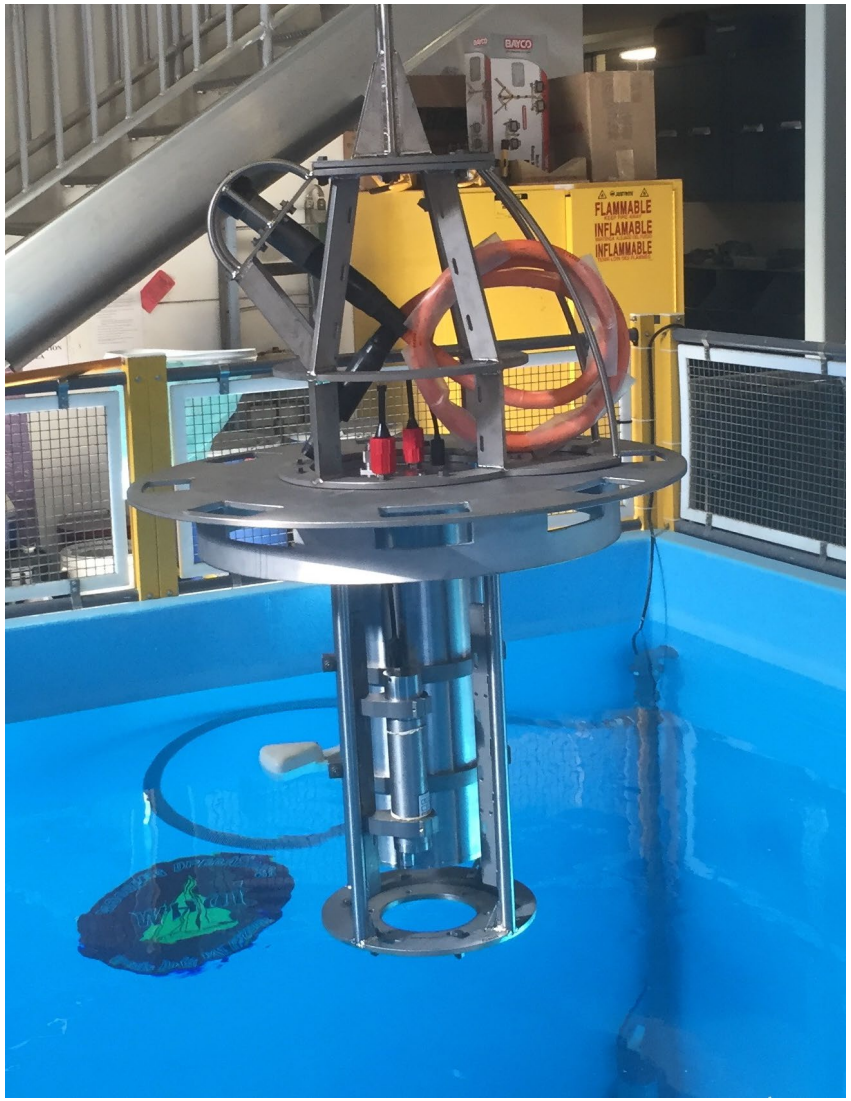
IODP Hole U1364A was instrumented with an ACORK (Advanced Circulation Obviation Retrofit Kit) in 2010 to allow monitoring and sampling of fluids from multiple zones within the ~330 m drilled formation. Pressure monitoring and fluid sampling is done via a multiline hydraulic umbilical strapped to the outside of the 10" I.D. casing. Hydraulic lines from each level pass successively through packers and screens above and are then plumbed into a seafloor framework that houses sampling and testing ports, pressure sensors, and data loggers.

Bottom Instrument Package (BIP)

The downhole assembly (Borehole Instrument Package or BIP) contains a Nanometrics 120PH broadband seismometer, two identical 2-axis nano-radian resolution Halliburton-Denali tiltmeters, two coarse resolution 1-axis tiltmeters from Jewell Instruments, and a 6-channel Quanterra Q330 data logger with a QEP piggy-back 3-channel A/D board. The length of the pressure housing is 52”.

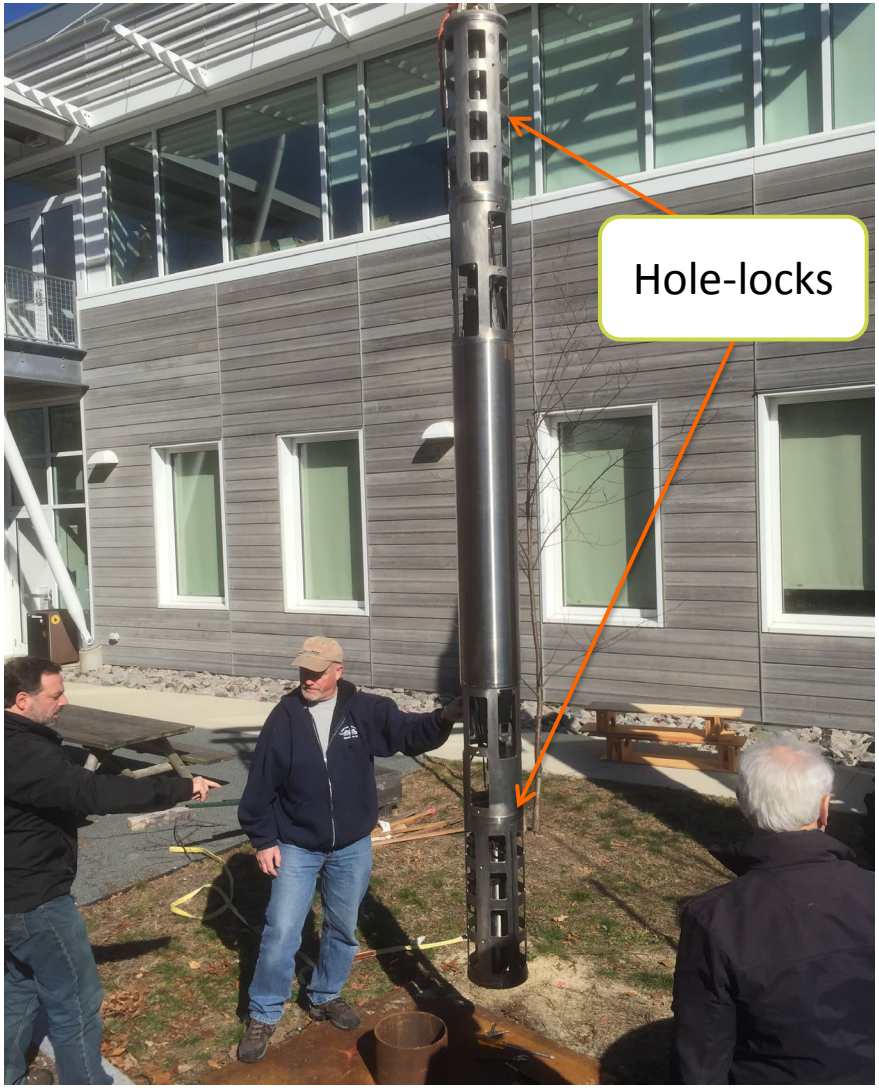
Surface Interface Instrument Module (SIIM)

The BIP is connected to the Surface Interface Instrument Module (SIIM) that sits in the ACORK via a 14-pair armored cable. The SIIM holds a Quanterra PB44 Baler storage device, a Conemtech PTP receiver, a EDS-510A managed Ethernet switch, power conversion electronics (440Vdc –> 48Vdc; 48V–> 12,Vdc; 48Vdc--> 3.3 Vdc, internal leak, humidity, pressure and temperature sensors, a controller mother board carrying 5 isolated power & serial-to-Ethernet modules, UMC connection to seabed cable, and an RBR thermistor chain data logger that is external to the main housing.



Test Borehole Construction

To test the hole-locks on the BIP (Borehole Instrument Package) and evaluate sensor performance, we drilled and cased a 20’ deep 10’ I.D. borehole just outside the WHOI OBS Lab. The I.D. of the borehole is the same as at IODP Hole U1364A.

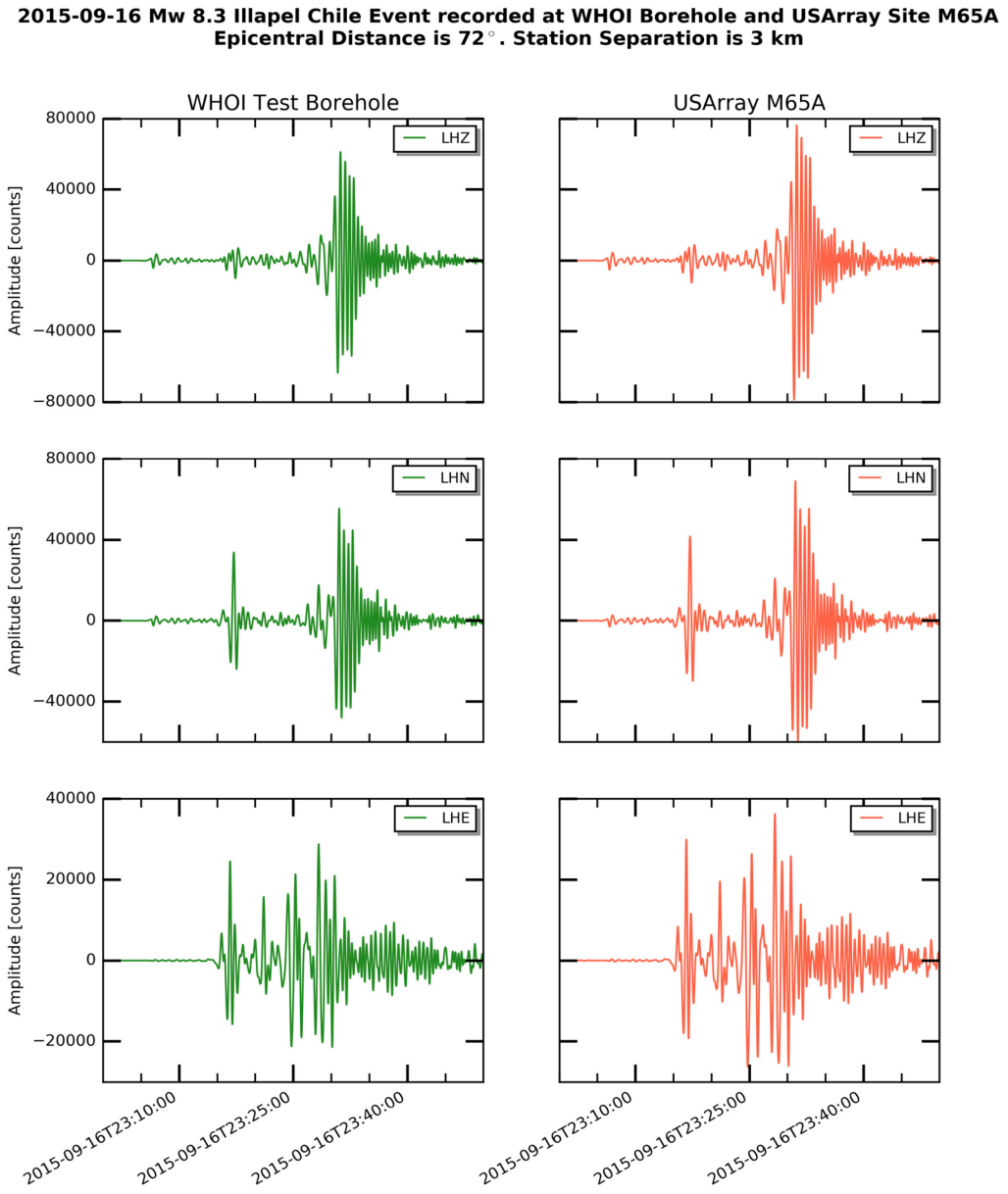


Tim Kane, watched by Jeff O' Brien (left) and Keith von der Heydt (right) guides the BIP (Bottom Instrument Package) into the borehole just outside the OBS Lab.

Testing of BIP and SIIM at the WHOI Borehole

To evaluate the complete system from BIP to SIIM via the ~280 m armored cable, we installed the BIP in the WHOI test borehole for a total duration of approx. 6 months.

A number of large earthquakes allowed comparison of the BIP's seismometer performance with the performance of a USArray station nearby. The figure shows ground motion in the period band 100—30 s generated by a large event offshore Chile. The response of the Keck-funded seismometer in the WHOI Borehole compares well to that of the USArray station M65A located ~3 km away.



Deployment in IODP Borehole U1364A

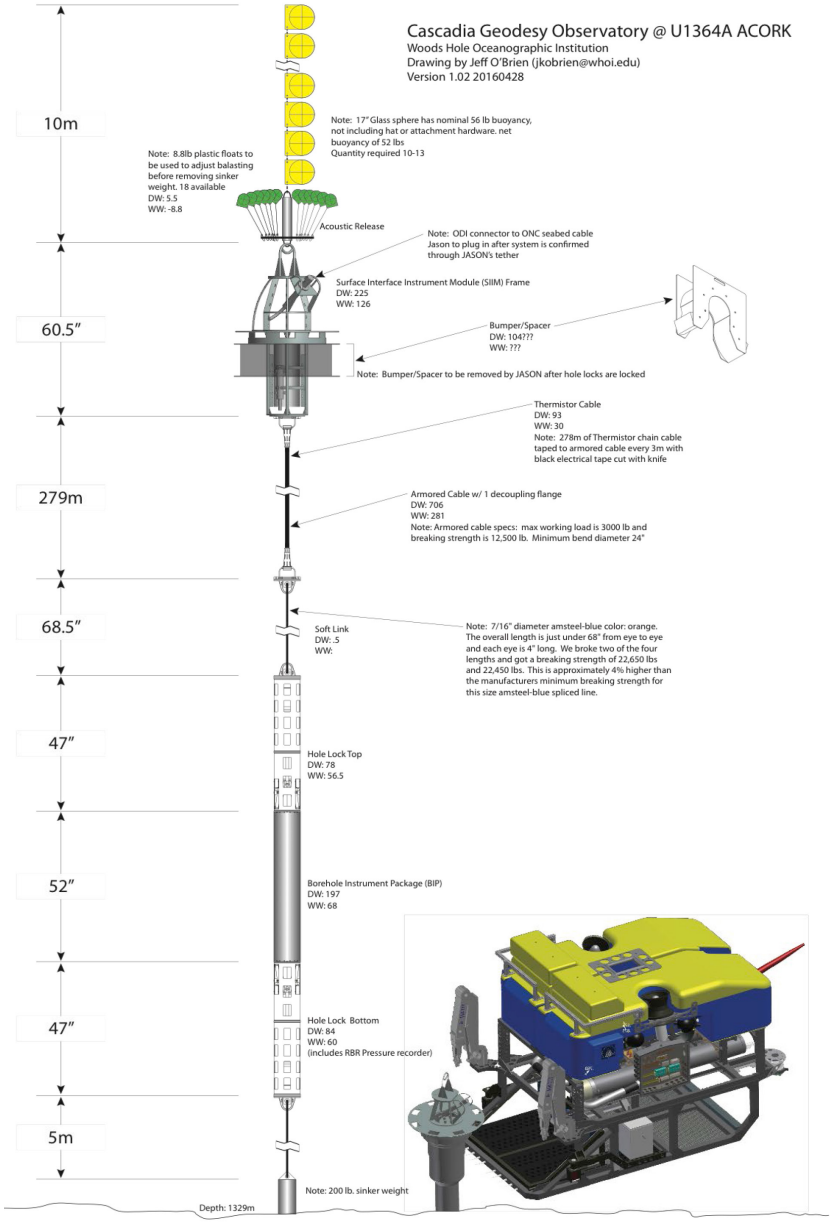
BIP (left) and SIIM (middle) being deployed from the R/V Sikuliaq on July 1, 2016.
(Right) Securing the 24-sensor, 278-m long thermistor cable to the to the armored cable extending from the BIP to the SIIM. The temperature data are logged by an RBR logger external to the SIIM but mounted in frame.

Seafloor Configuration

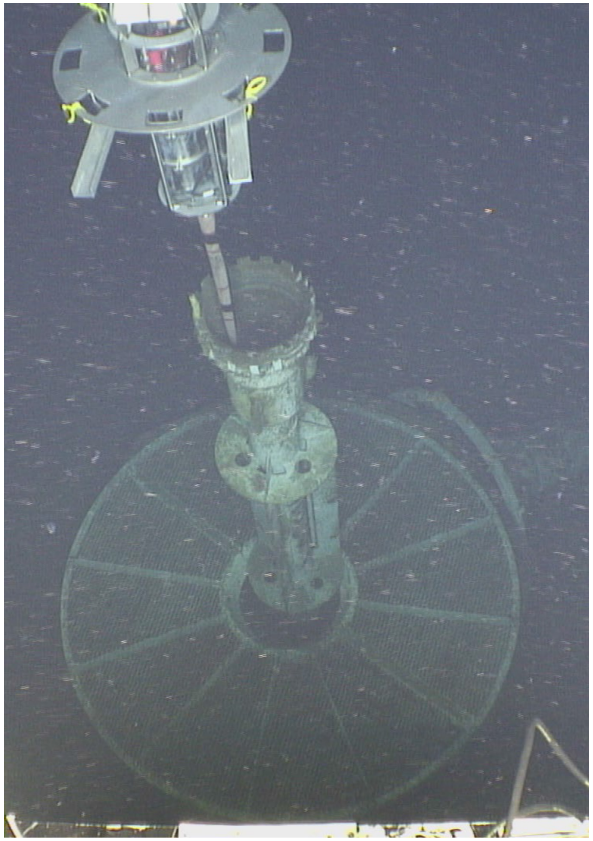
Cartoon showing the configuration of the complete borehole instrument string sitting on the seafloor prior to being picked up by Jason and transited to Hole U1364A.

The glass and plastic balls were used to control the ballasting of the instrument package during transit and insertion only.

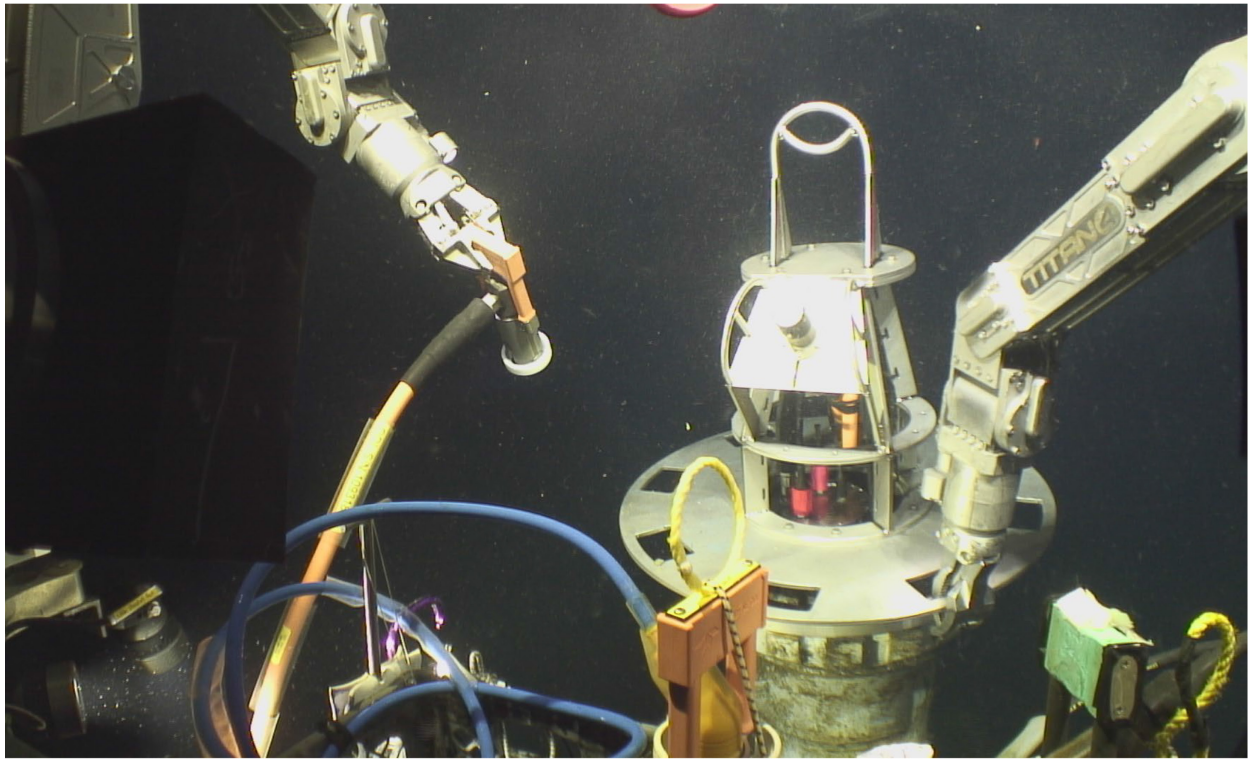
The sinker weight was detached prior to to transit. (Drawing by Jeff O' Brien, WHOI)



Installation and Hook-Up



SIIM (Surface Interface Instrument Module) Package about to impact the ACORK.



Jason ROV about to plug into SIIM. Because the extension cable between the borehole and ONC node at Clayoquot slope was not working, the BIP and SIIM were powered only when Jason was connected to the SIIM. This was corrected in June 2017 when a new extension cable was laid.

Station CQS64 was connected to the Clayoquot Slope node of the Ocean Networks Canada NEPTUNE Observatory in June 2017. The 3 km long extension cable provides power, timing, and internet connectivity.

The figure on the right shows ground motion in the period band 200—20 s generated by a large event at the western end of the Aleutians. The Keck-funded borehole station is CQS64. Station NC89 is a seafloor station located ~3 km from CQS64.