Ocean Bottom Seismology at Woods Hole Oceanographic Institution: Towards A Continuous Presence in the Deep Ocean

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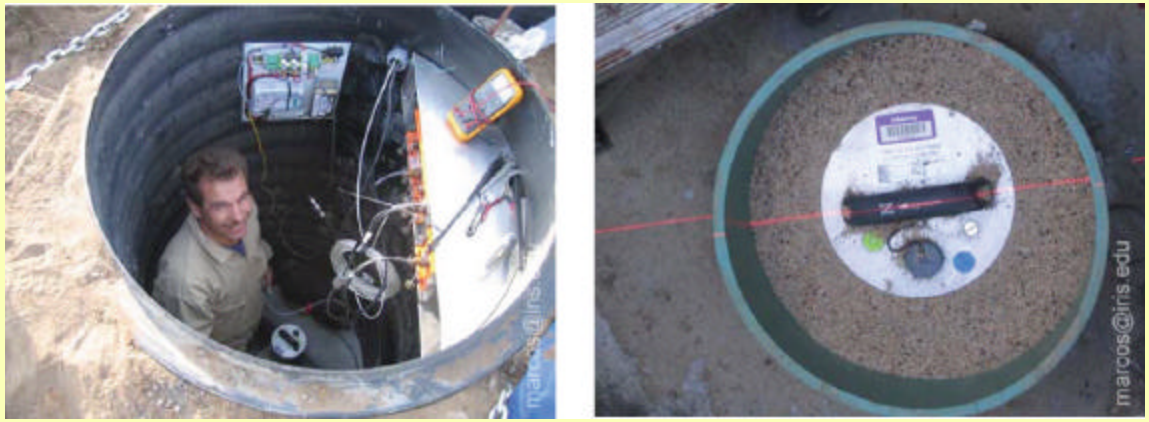
John Collins

Seismology: The Premier Tool for the Determination of Earth's Internal Structure

- A seismometer is a device for recording ground motion, typically in three orthogonal directions: up/down, and two horizontal azimuths. Ground motion might be due to an earthquake at the other side of the globe, or might be due to an airgun array at a distance of a few tens of kilometers.

- Seismic frequency band extends from about 54 minutes ("football" mode excited by large earthquake such as the December 26, 2004 Sumatra earthquake) to 50 Hz, i.e. 5 orders of magnitude. Magnitude of ground motion ranges from 10^{-10} m/s^2 to 2 g, i.e. over 11 orders of magnitude.

- Seismology tells us how the velocities of elastic waves (P and S) varies within the earth. Knowing the velocities, we can infer composition, deformation fabric, presence of melt, etc.



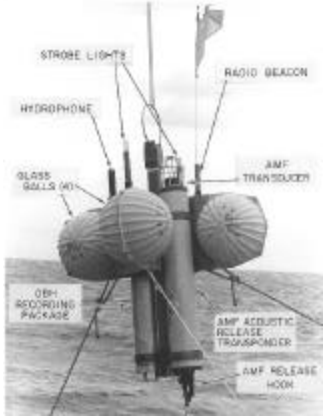
Ocean Bottom Seismology at WHOI

- WHOI built its first Ocean Bottom Seismograph (OBS) in 1976. It carried a hydrophone only, so in fact it was an Ocean Bottom Hydrophone (OBH) rather than an OBS. First generation OBH was entirely analog. Used for recording airgun shots and mid-ocean ridge microearthquakes.

- 1982-2000: Multiple generations of digital OBH.

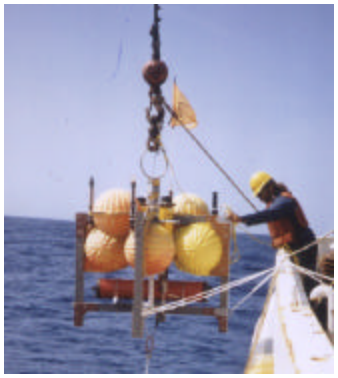
- 1990: Development of OBS with a three-component 1 Hz seismometer.

- 1999: Two OBS designs funded by OBSIP: short-period OBS for active-source and microearthquake-monitoring experiments; and a broadband OBS for long-term (1+ years) deployments that record teleseismic experiments. and and broadband OBS

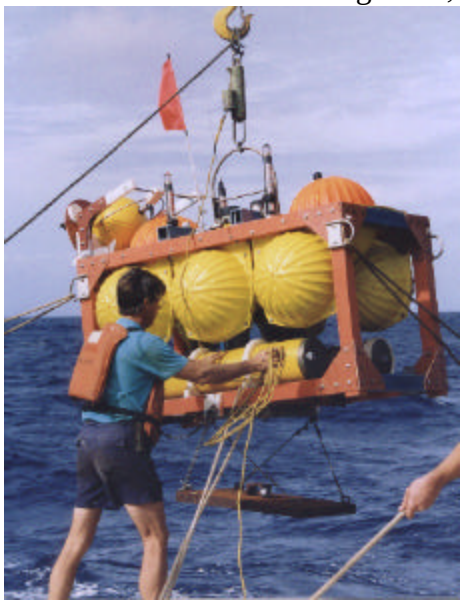


WHOI Analog OBH, 1976

WHOI Digital OBH, 1981

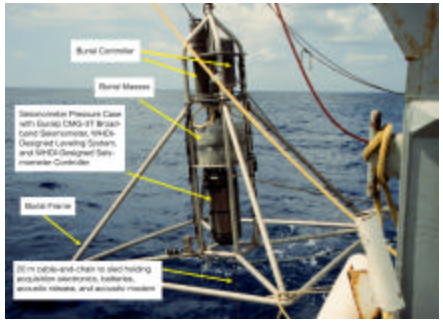


WHOI 2nd Generation Digital OBH, 1991

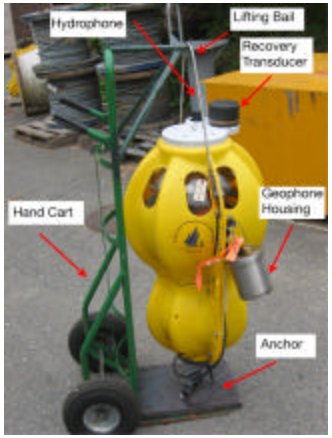


WHOI "ONR" OBS, 1991

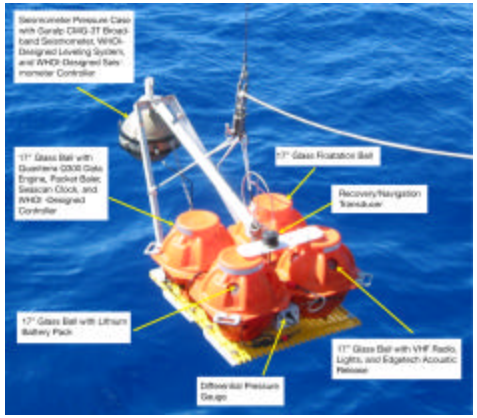
WHOI "ORB" 3rd-Generation OBH, 1996



WHOI Buriable Broadband OBS, 1998



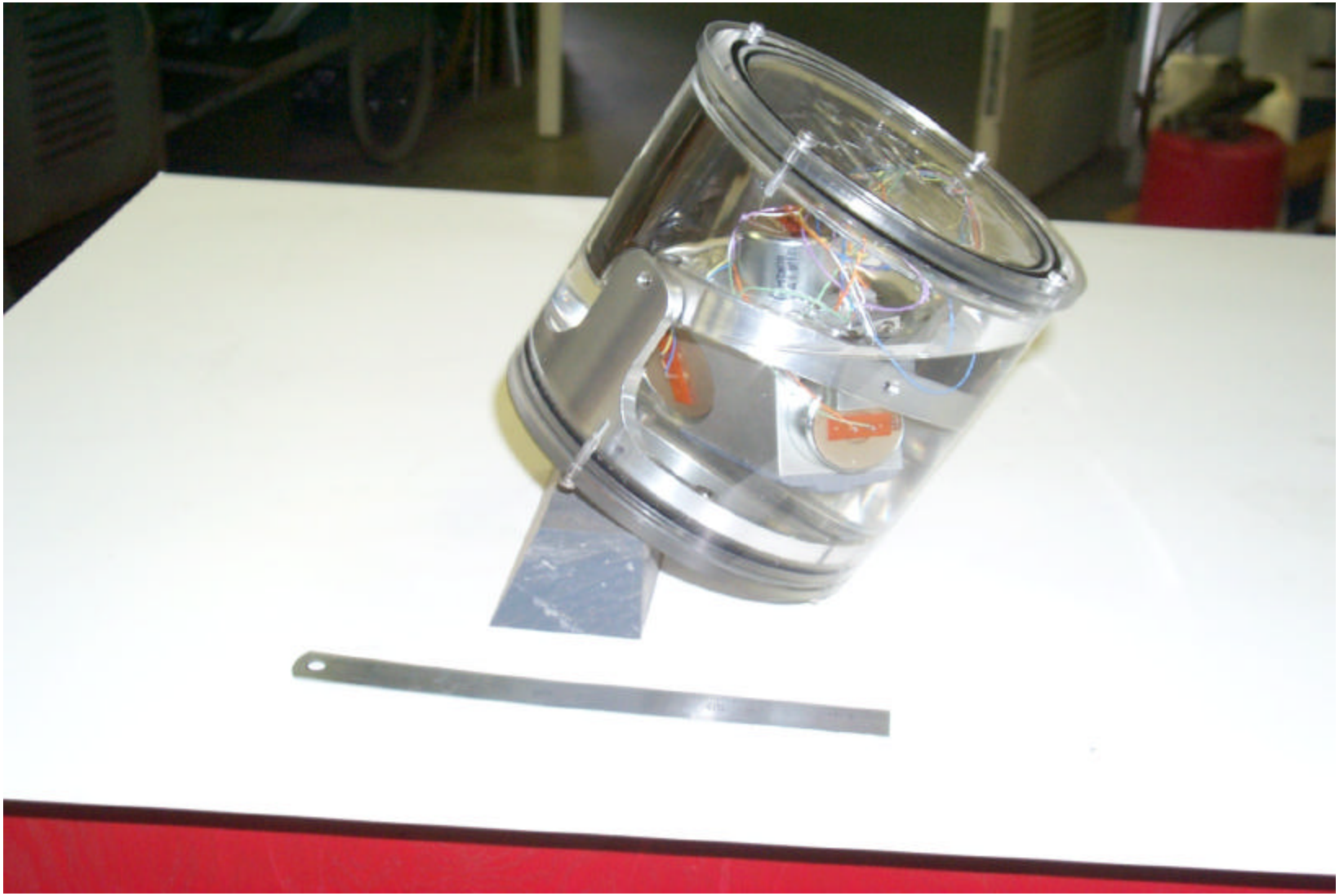
WHOI NSF-OBSIP Short-Period OBS ("D2"), 2003

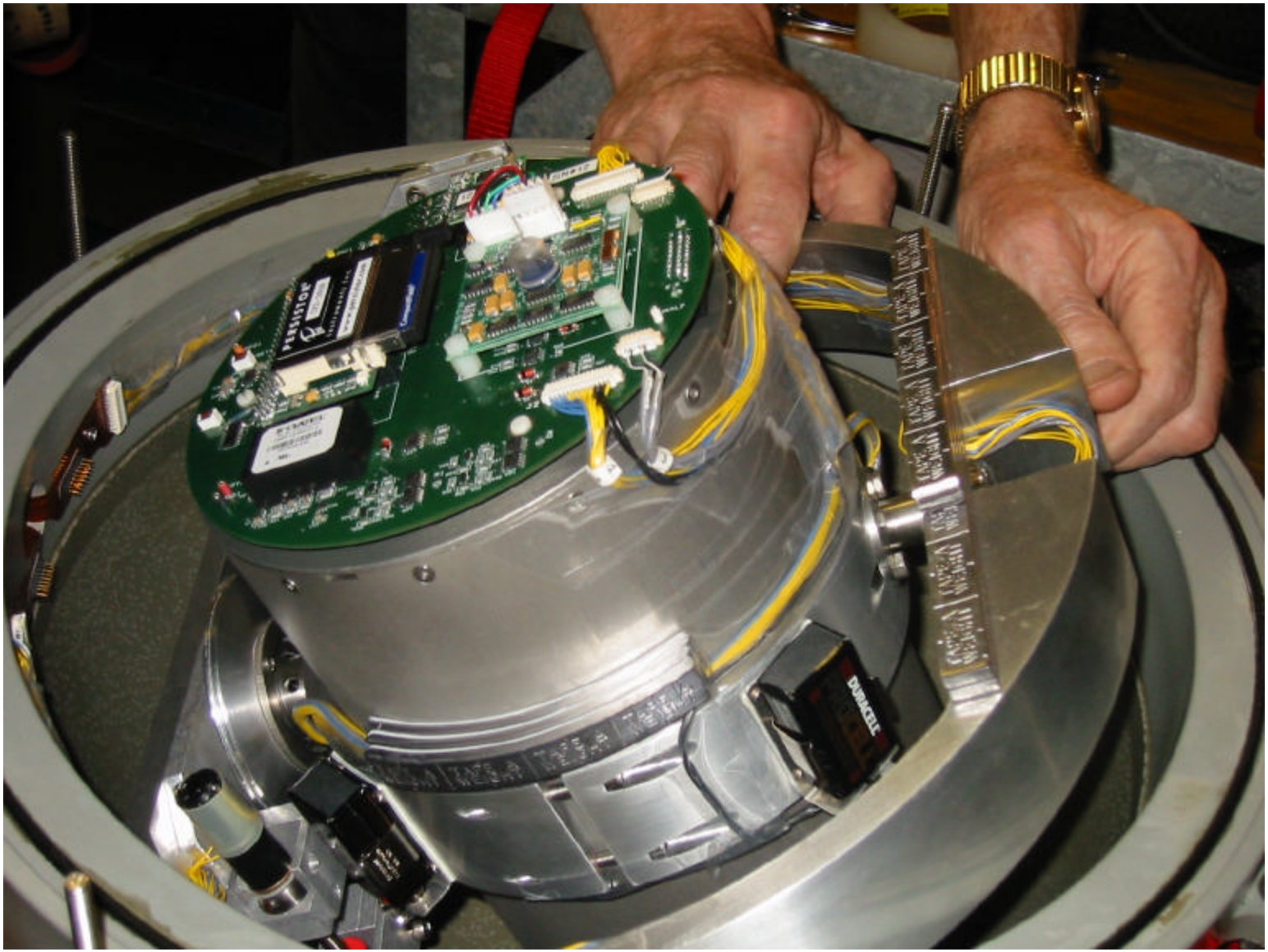


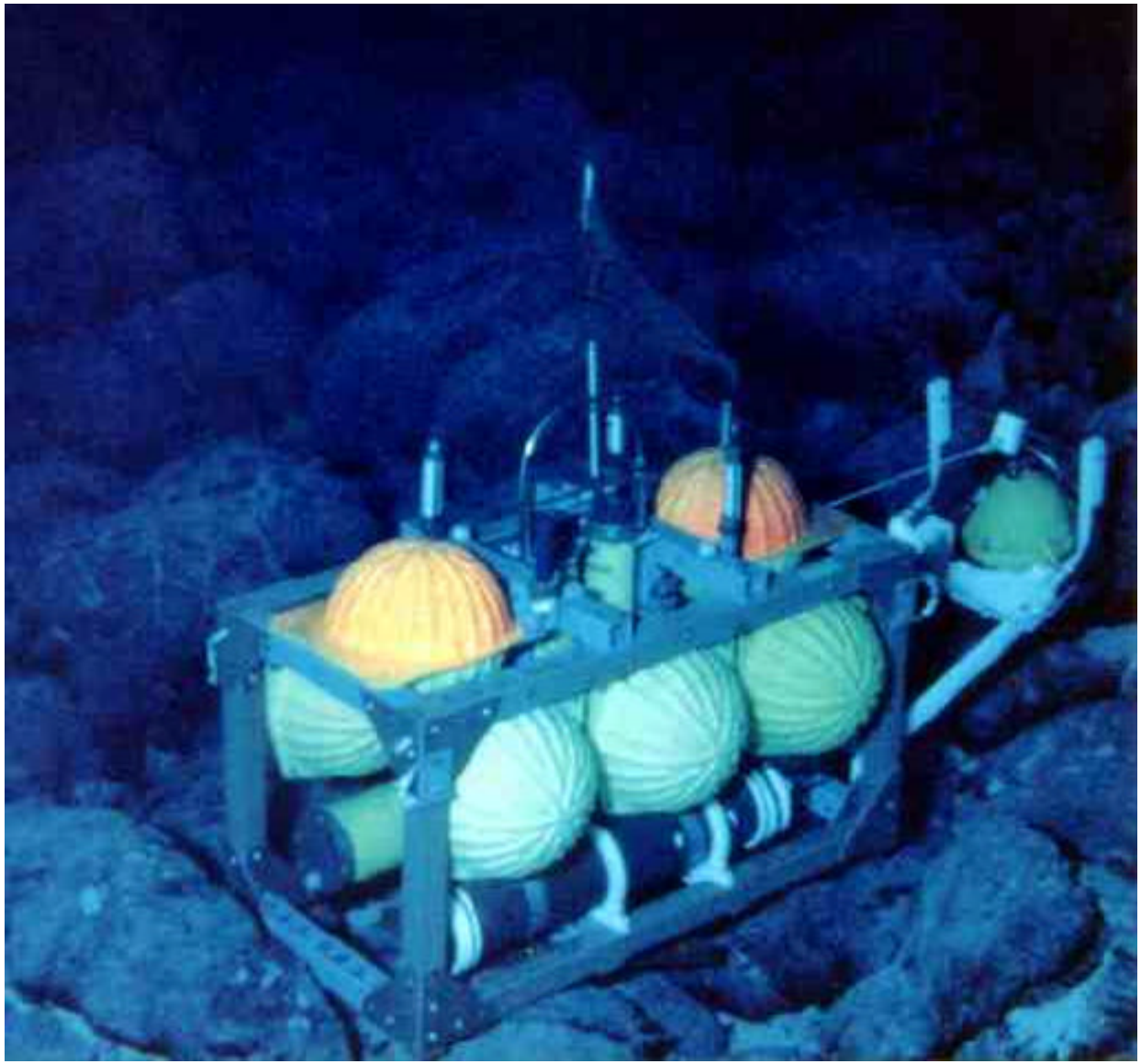
WHOI NSF-OBSIP BroadBand OBS, 2004

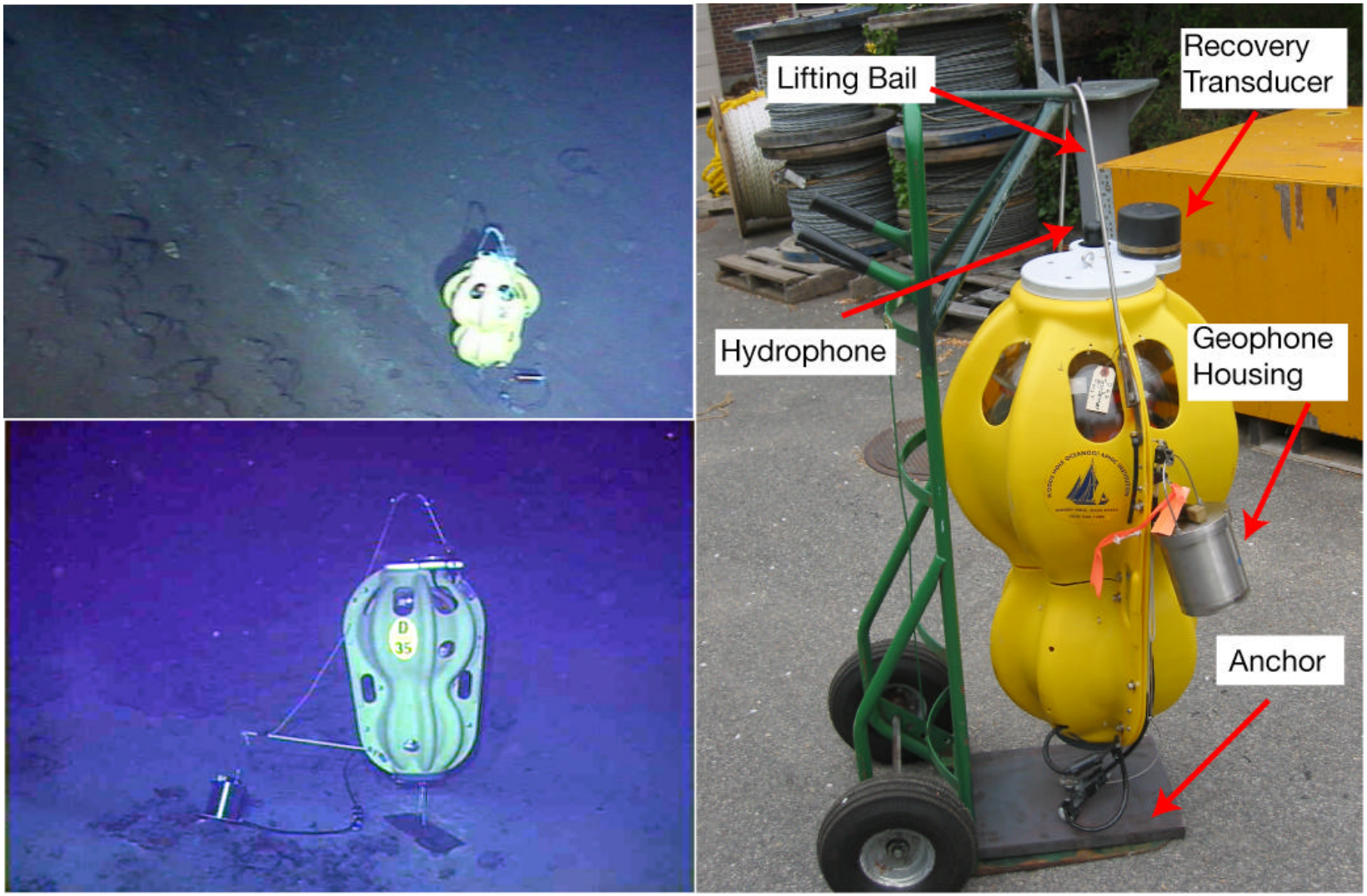
Seismology on the Ocean Floor

- Challenges: Power; Timing; Leveling; Coupling Seismometer to Seafloor (Cannot build vault).
- Over course of last few years, power requirements of 24-bit A/D converters have decreased to 0.75 W or less. Broadband seismometer draws ~0.5-0.6 W. Lithium battery cost for a one-year deployment is ~$5K.
- No GPS on the seafloor. Low-power (~100 mW) clocks have drift rates of a 1-3 ms/day - barely acceptable for some studies (surface waves), but inadequate for others (precise earthquake locations).
- Various leveling methods have been developed.
- Coupling is still a huge challenge.



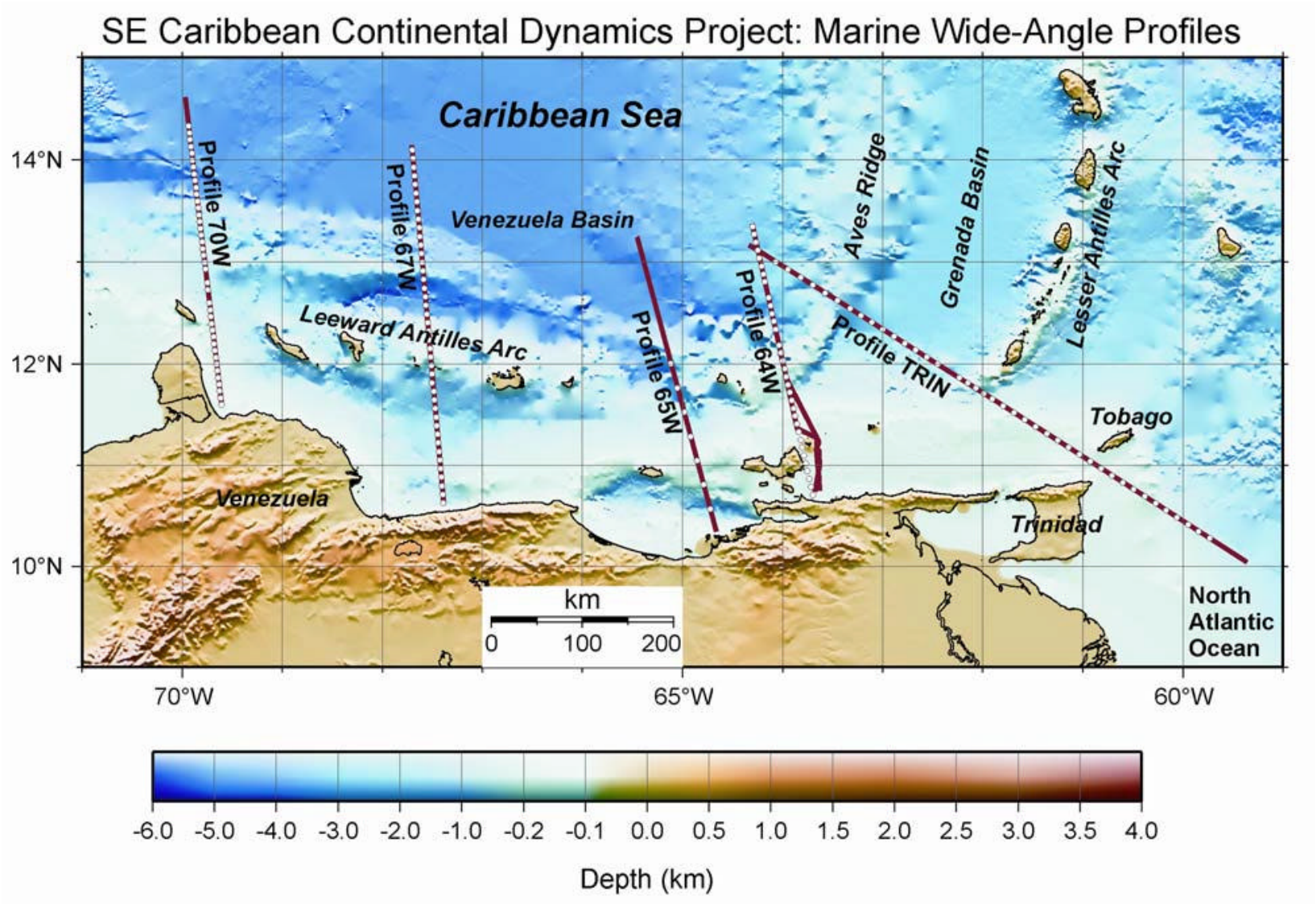

PERSISTOR
DURACELL



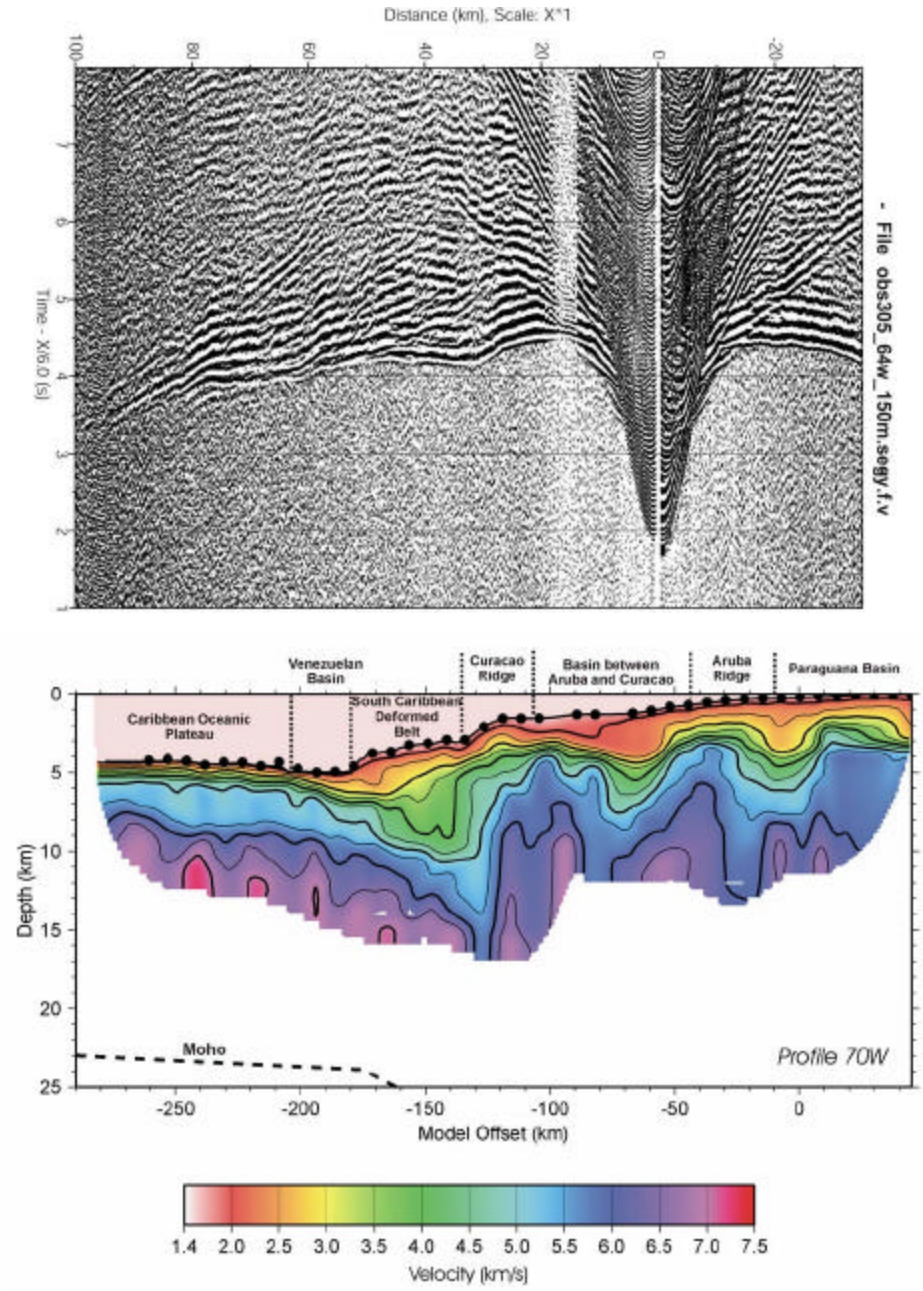


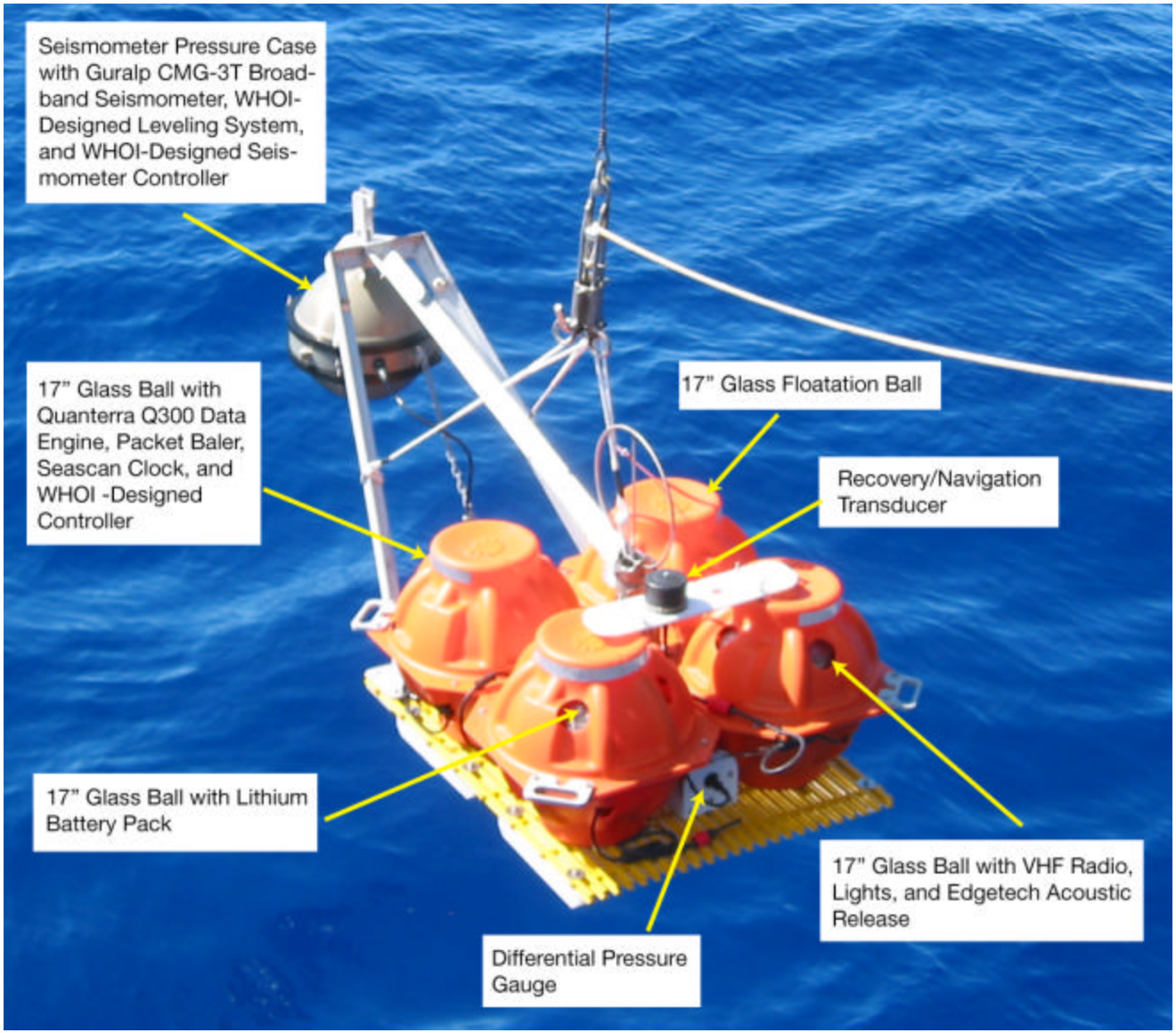
Views of the WHOI “D2” Short-Period OBS. The instrument is ~ 1m in height.


SONY

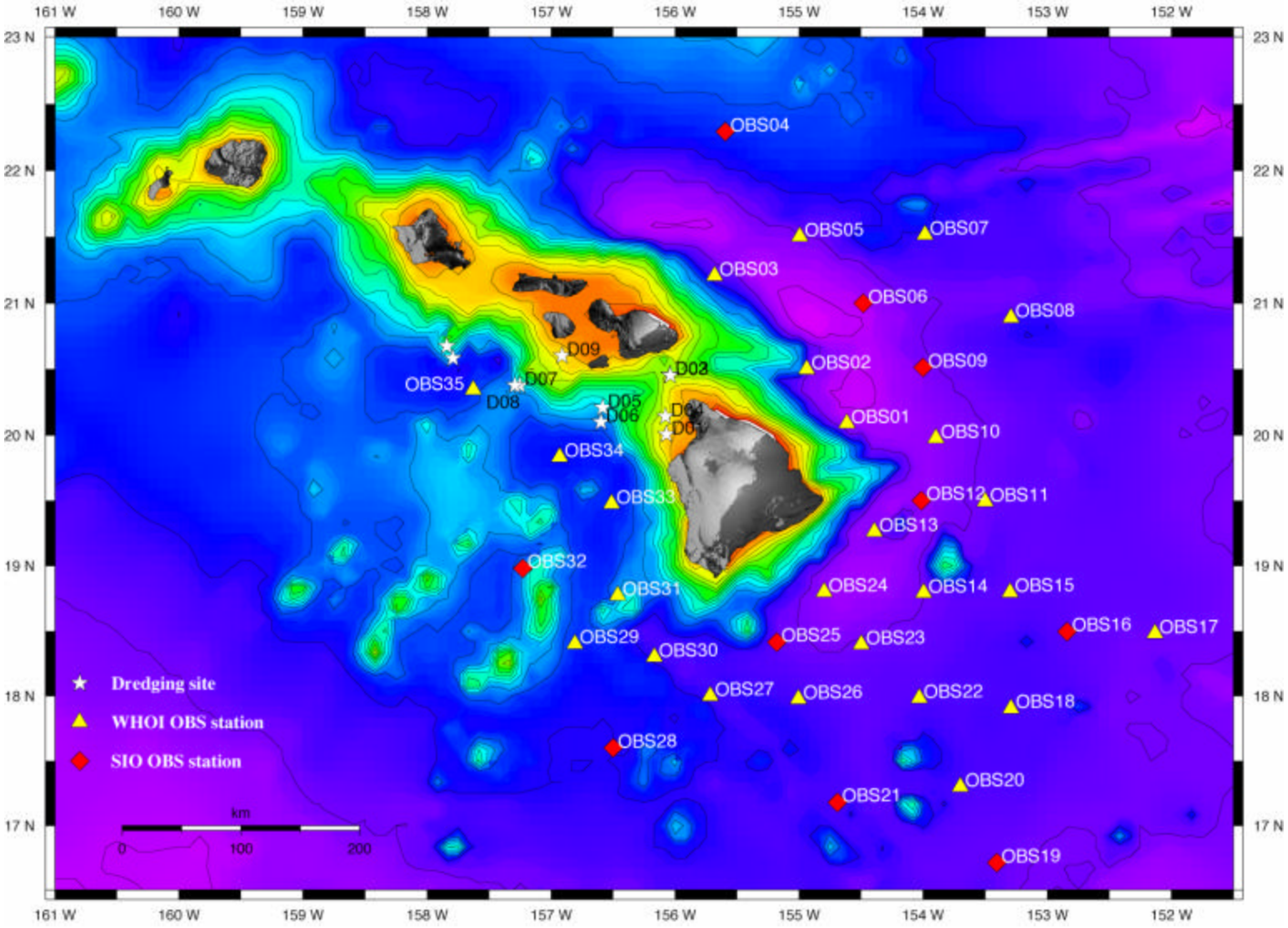

SE Caribbean Continental Dynamics Project: Marine Wide-Angle Profiles
Caribbean Sea
Venezuela Basin
Profile 70W
Profile 67W
Profile 65W
Profile 64W
Profile TRIN
Aves Ridge
Grenada Basin
Lesser Antilles Arc
Leeward Antilles Arc
Tobago
Trinidad
Venezuela
North Atlantic Ocean
km
0 100 200
14°N
12°N
10°N
70°W
65°W
60°W
-6.0 -5.0 -4.0 -3.0 -2.0 -1.0 -0.2 -0.1 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
Depth (km)

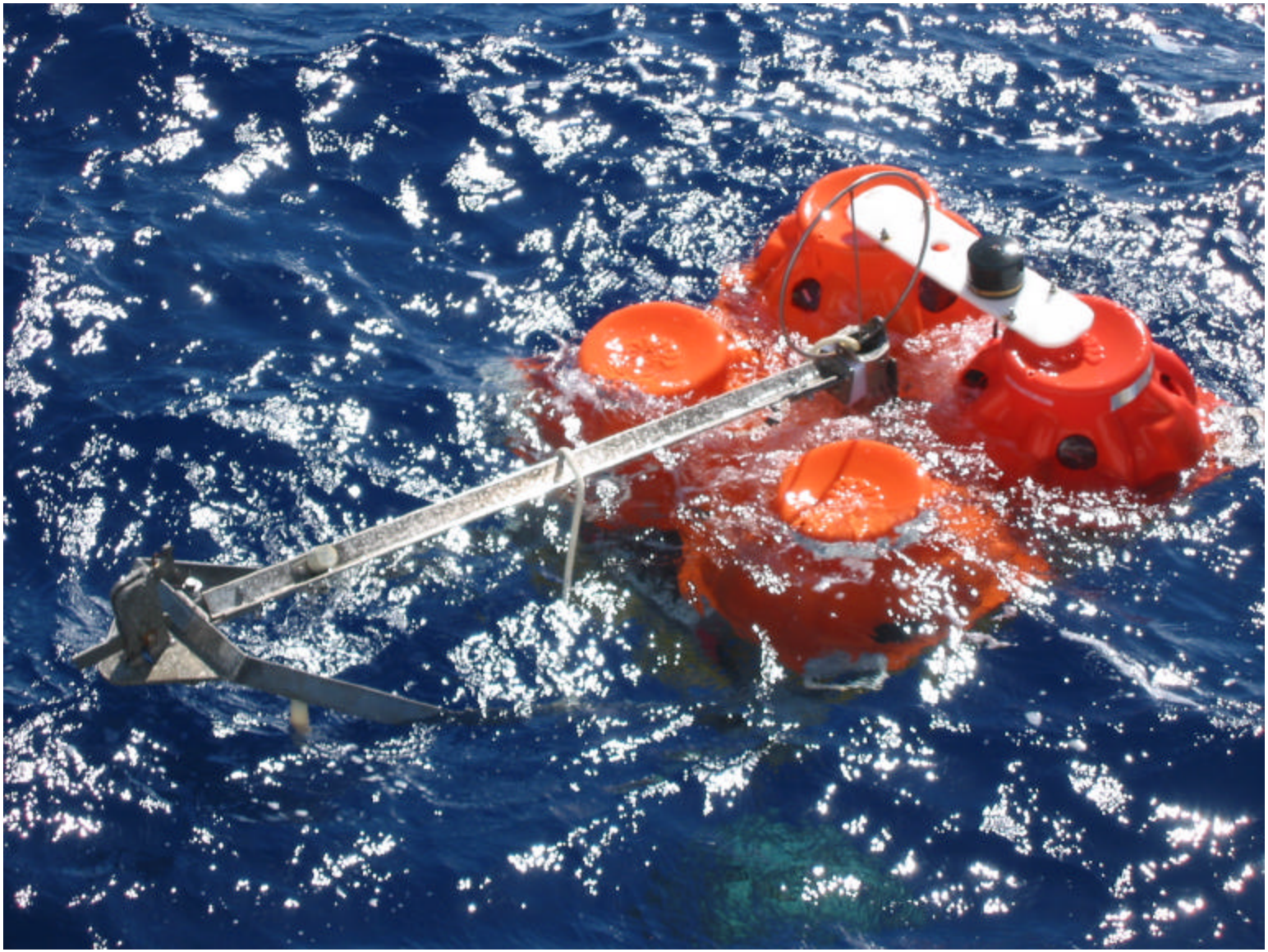

SE CARIBBEAN
SEISMIC CRUISE
RIV SEWARD JOHNSON II
OBS RECOVERY #100
MAY 21, 2004
ONLY 67 TO GO!
D
11

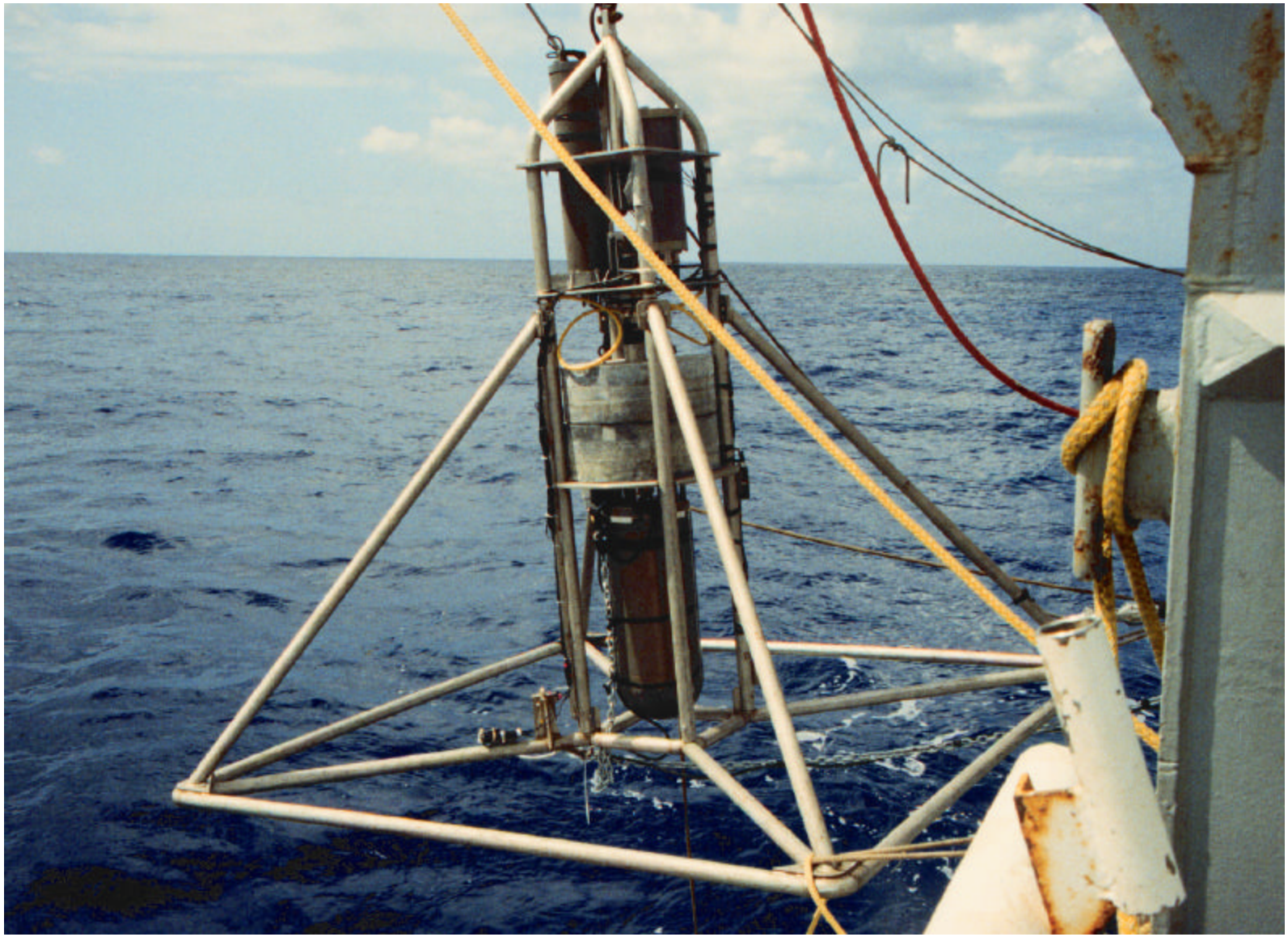

Distance (km), Scale: X*1
100
80
60
40
20
0
-20
Time - X/6.0 (s)
1
2
3
4
5
6
7
- File obs305_64w_150m.segy.f.v
Venezuelan Basin
Curacao Ridge
Basin between Aruba and Curacao
Aruba Ridge
Paraguana Basin
Caribbean Oceanic Plateau
South Caribbean Deformed Belt
Depth (km)
0
5
10
15
20
25
Moho
Profile 70W
-250
-200
-150
-100
-50
0
Model Offset (km)
1.4
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
Velocity (km/s)

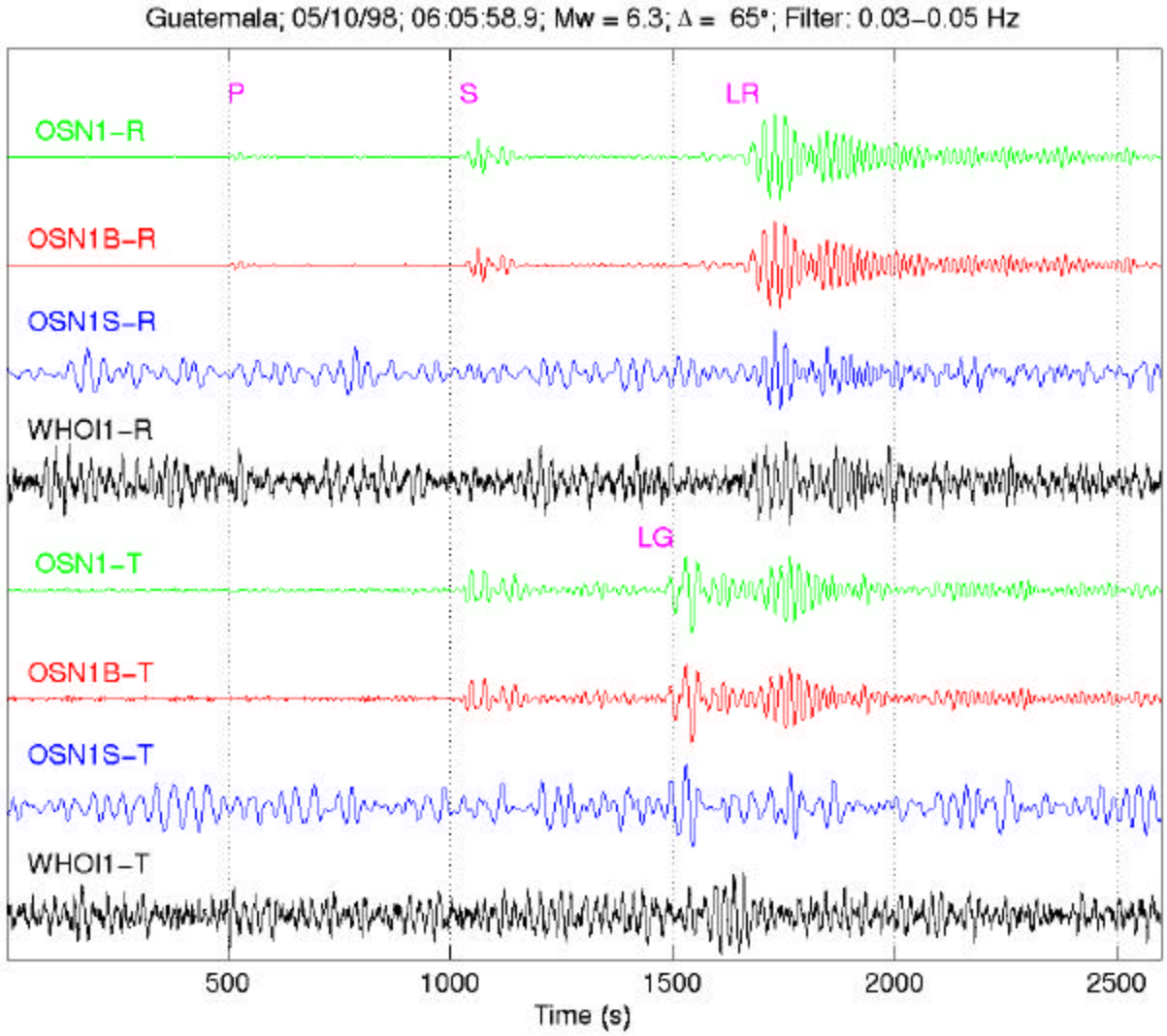

Seismometer Pressure Case with Guralp CMG-3T Broad-band Seismometer, WHOI-Designed Leveling System, and WHOI-Designed Seis-mometer Controller
17" Glass Ball with Quanterra Q300 Data Engine, Packet Baler, Seascan Clock, and WHOI -Designed Controller
17" Glass Floatation Ball
Recovery/Navigation Transducer
17" Glass Ball with Lithium Battery Pack
17" Glass Ball with VHF Radio, Lights, and Edgetech Acoustic Release
Differential Pressure Gauge

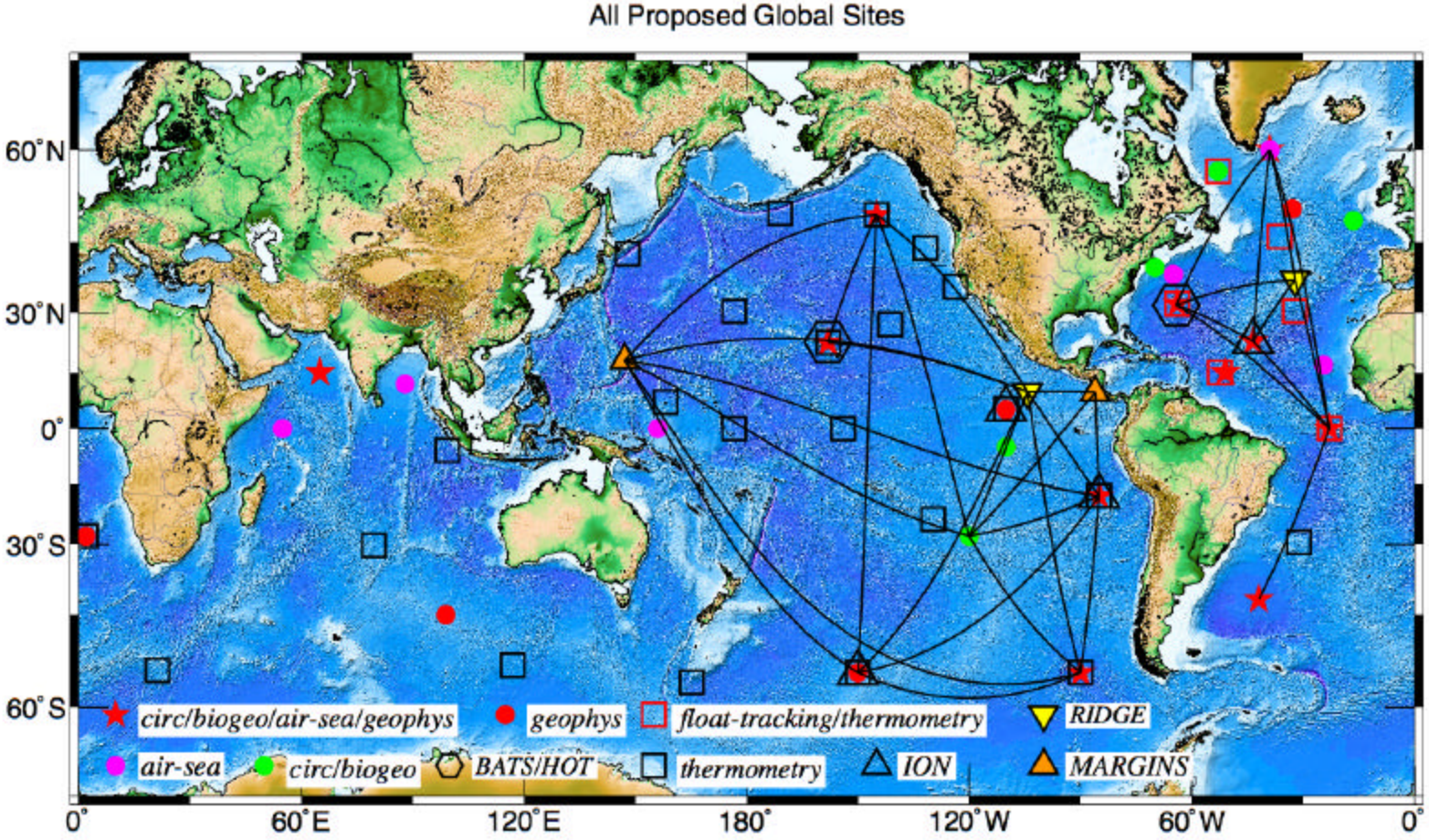
PLUME TUIM01MV - Station Map

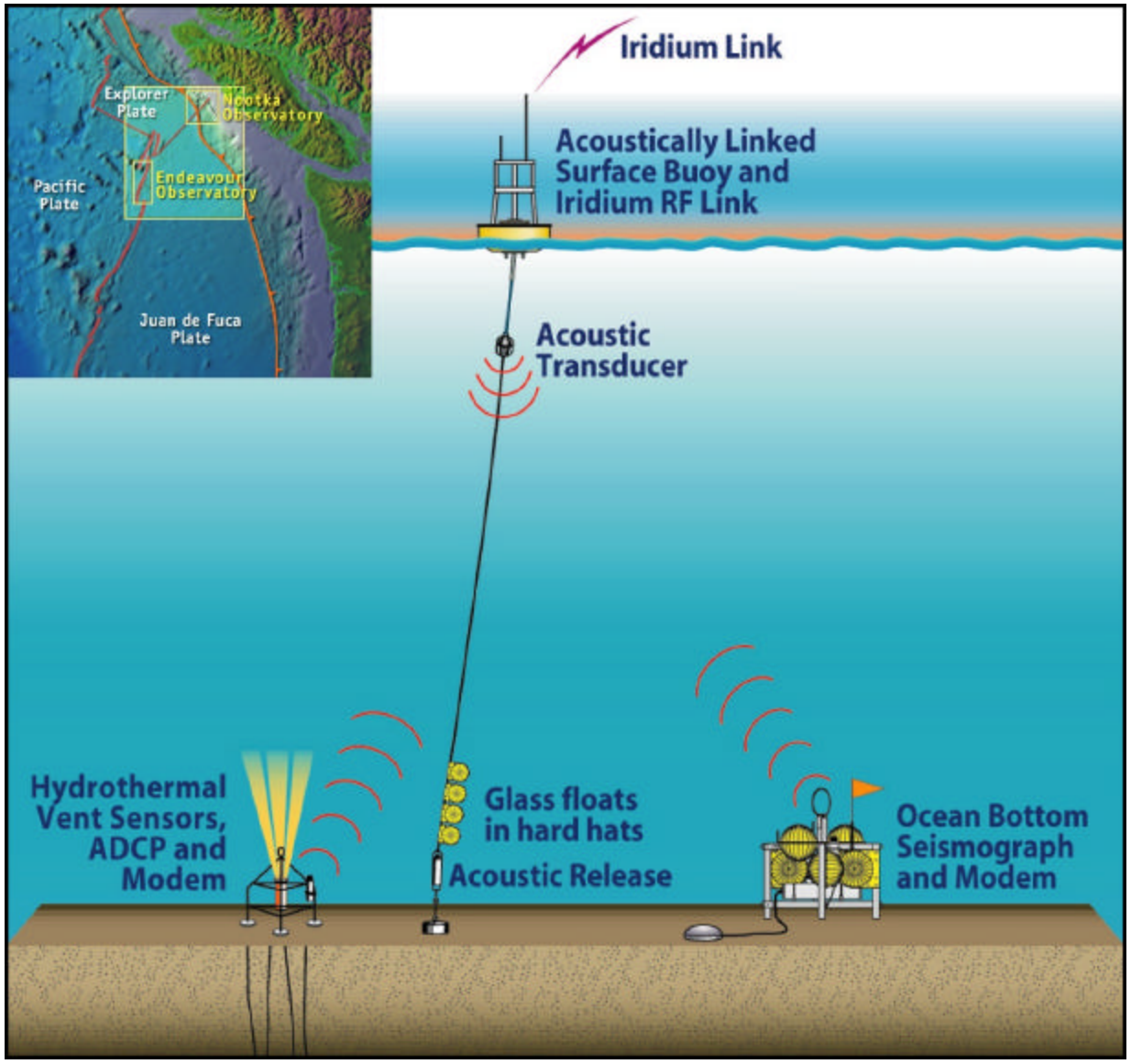


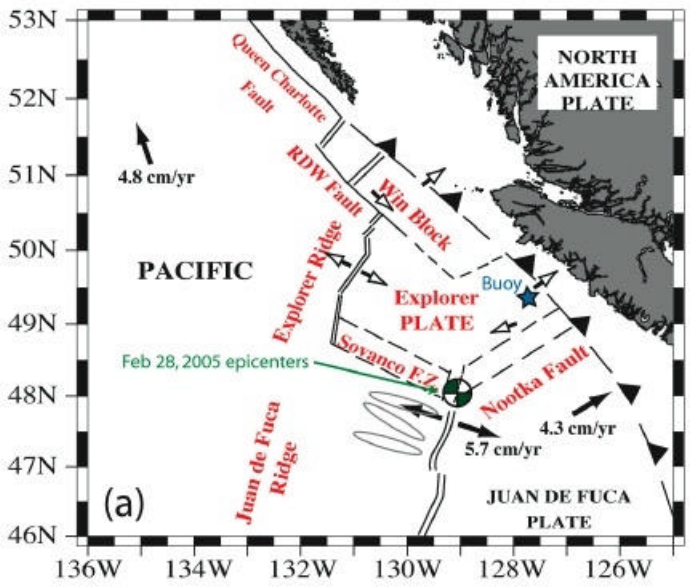


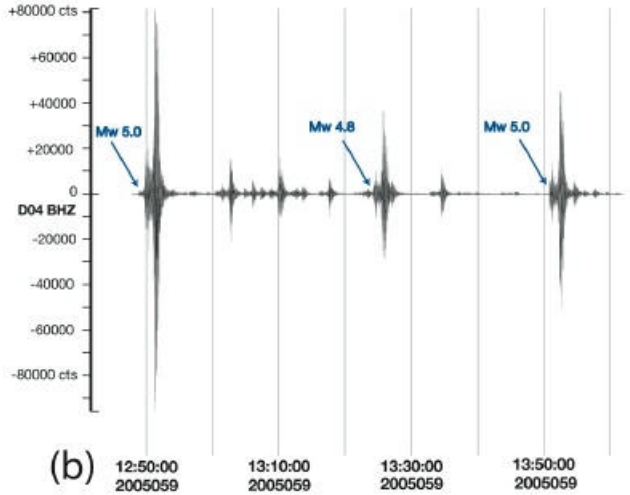


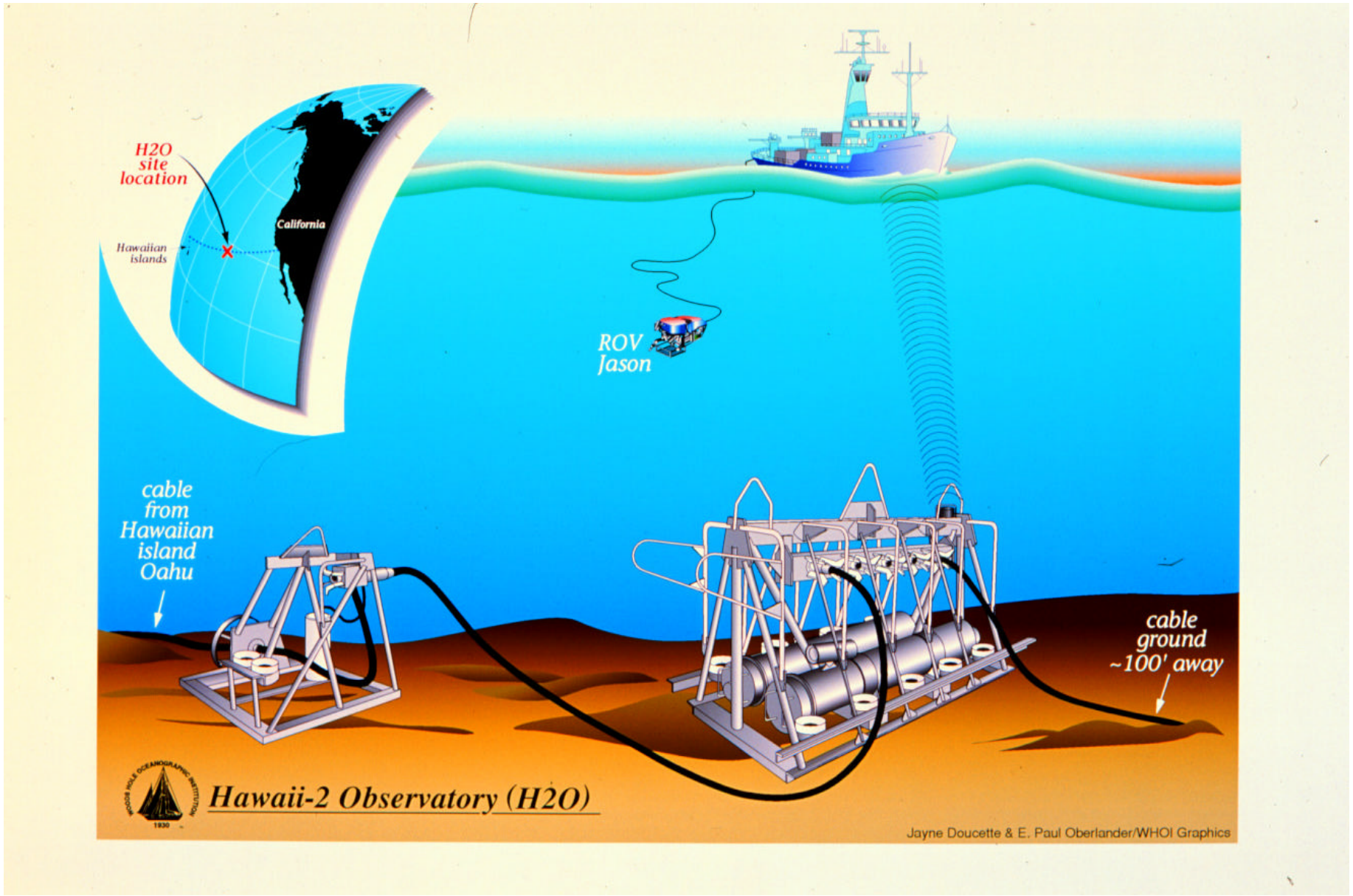

Guatemala; 05/10/98; 06:05:58.9; Mw = 6.3; Δ = 65°; Filter: 0.03–0.05 Hz
P
S
LR
OSN1–R
OSN1B–R
OSN1S–R
WHOI1–R
LG
OSN1–T
OSN1B–T
OSN1S–T
WHOI1–T
500
1000
1500
2000
2500
Time (s)

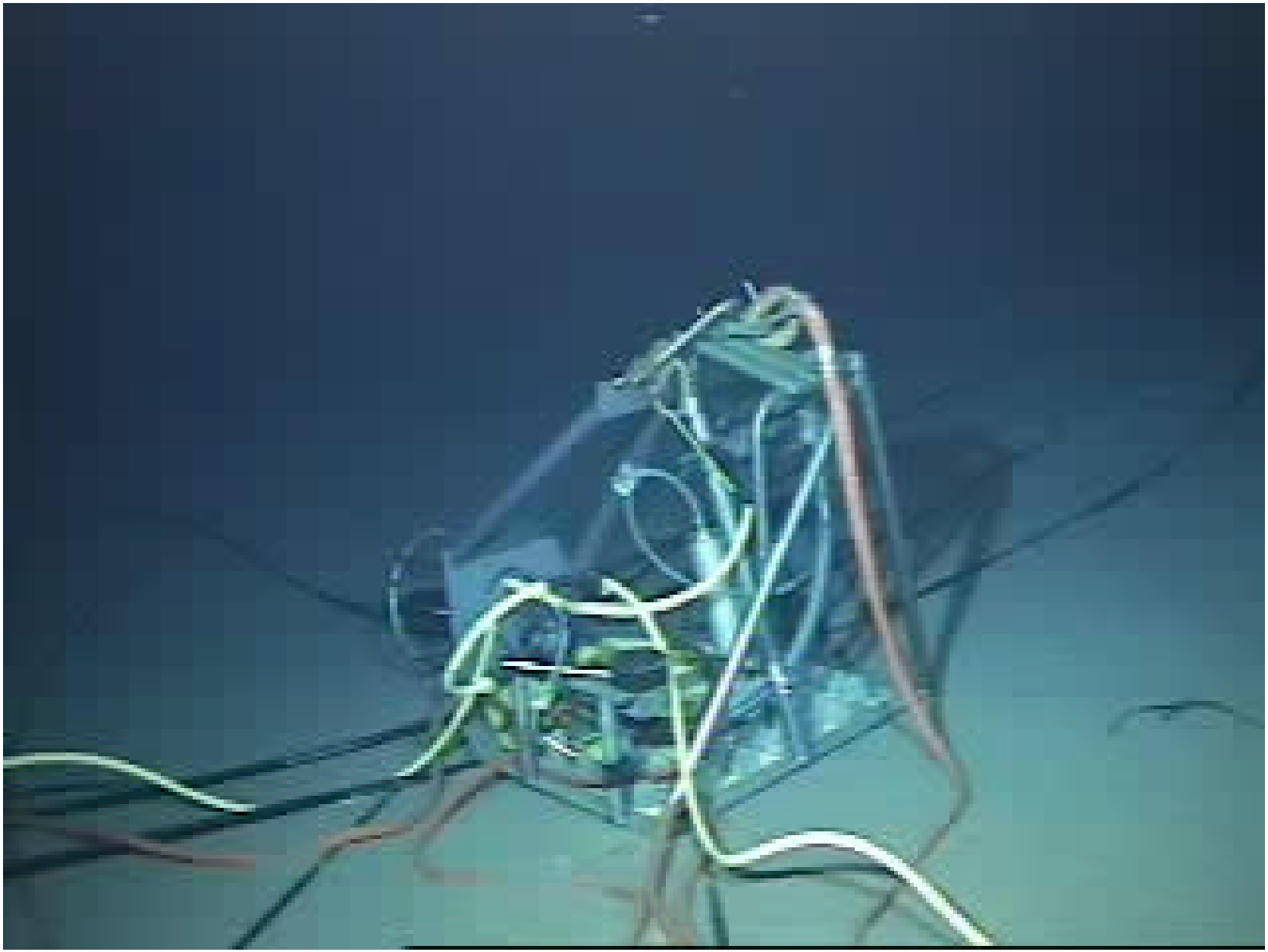

All Proposed Global Sites
60˚N
30˚N
0˚
30˚S
60˚S
0˚
60˚E
120˚E
180˚
120˚W
60˚W
0˚
circ/biogeo/air-sea/geophys
geophys
float-tracking/thermometry
RIDGE
air-sea
circ/biogeo
BATS/HOT
thermometry
ION
MARGINS

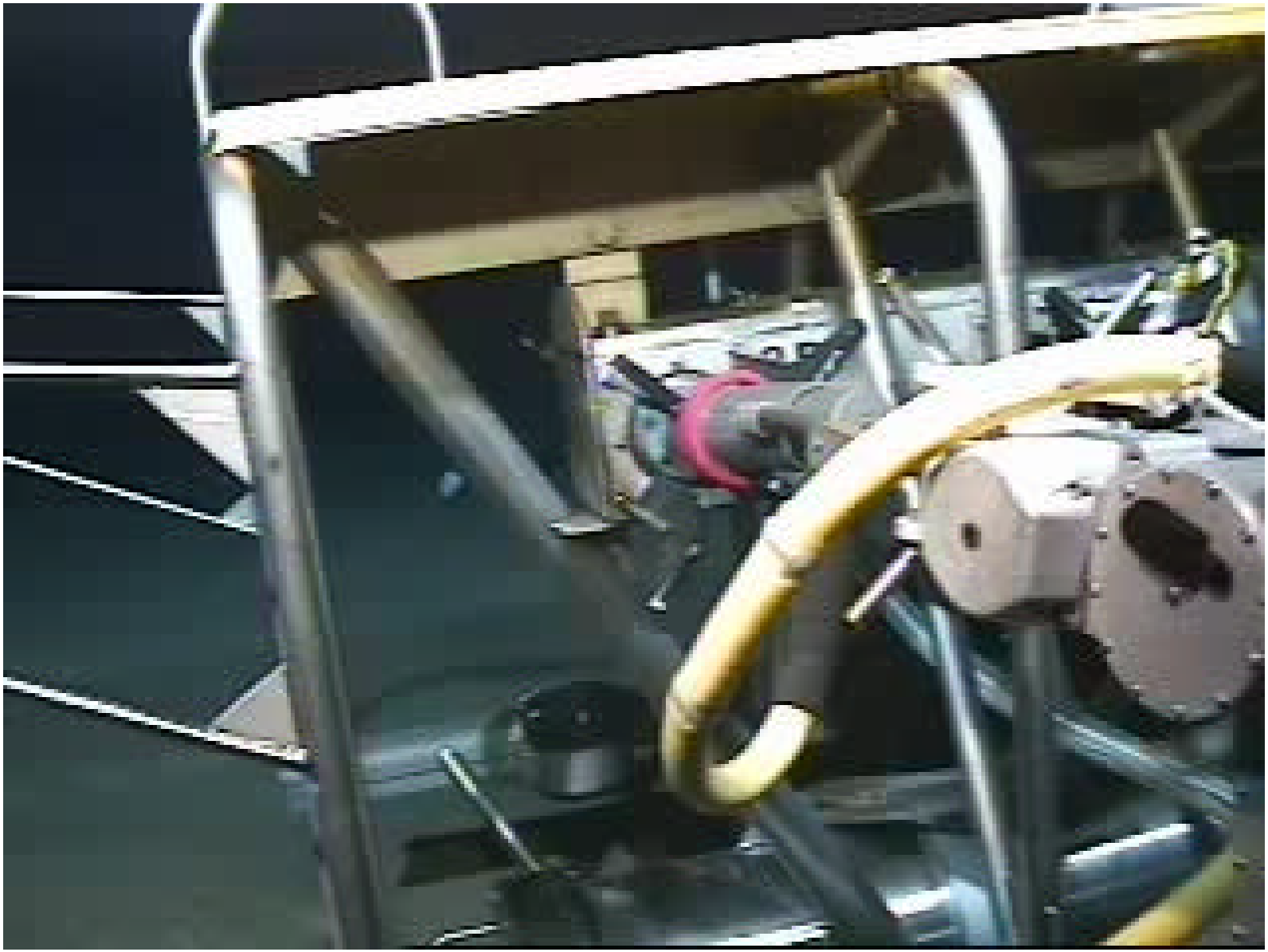

Iridium Link
Acoustically Linked
Surface Buoy and
Iridium RF Link
Acoustic
Transducer
Explorer
Plate
Nootka
Observatory
Pacific
Plate
Endeavour
Observatory
Juan de Fuca
Plate
Hydrothermal
Vent Sensors,
ADCP and
Modem
Glass floats
in hard hats
Acoustic Release
Ocean Bottom
Seismograph
and Modem


53N
52N
51N
50N
49N
48N
47N
46N
136W
134W
132W
130W
128W
126W
NORTH AMERICA PLATE
Queen Charlotte Fault
RDW Fault
Win Block
4.8 cm/yr
PACIFIC
Explorer Ridge
Buoy
Explorer PLATE
Feb 28, 2005 epicenters
Soyanco F.Z.
Nootka Fault
4.3 cm/yr
5.7 cm/yr
Juan de Fuca Ridge
(a)
JUAN DE FUCA PLATE


+80000 cts
+60000
+40000
+20000
0
D04 BHZ
-20000
-40000
-60000
-80000 cts
Mw 5.0
Mw 4.8
Mw 5.0
(b)
12:50:00
2005059
13:10:00
2005059
13:30:00
2005059
13:50:00
2005059


H2O site location
California
Hawaiian islands
ROV Jason
cable from Hawaiian island Oahu
cable ground ~100' away
Hawaii-2 Observatory (H2O)
Jayne Doucette & E. Paul Oberlander/WHOI Graphics





WHAT NEXT ??

ORION

NEPTUNE

BBOBS