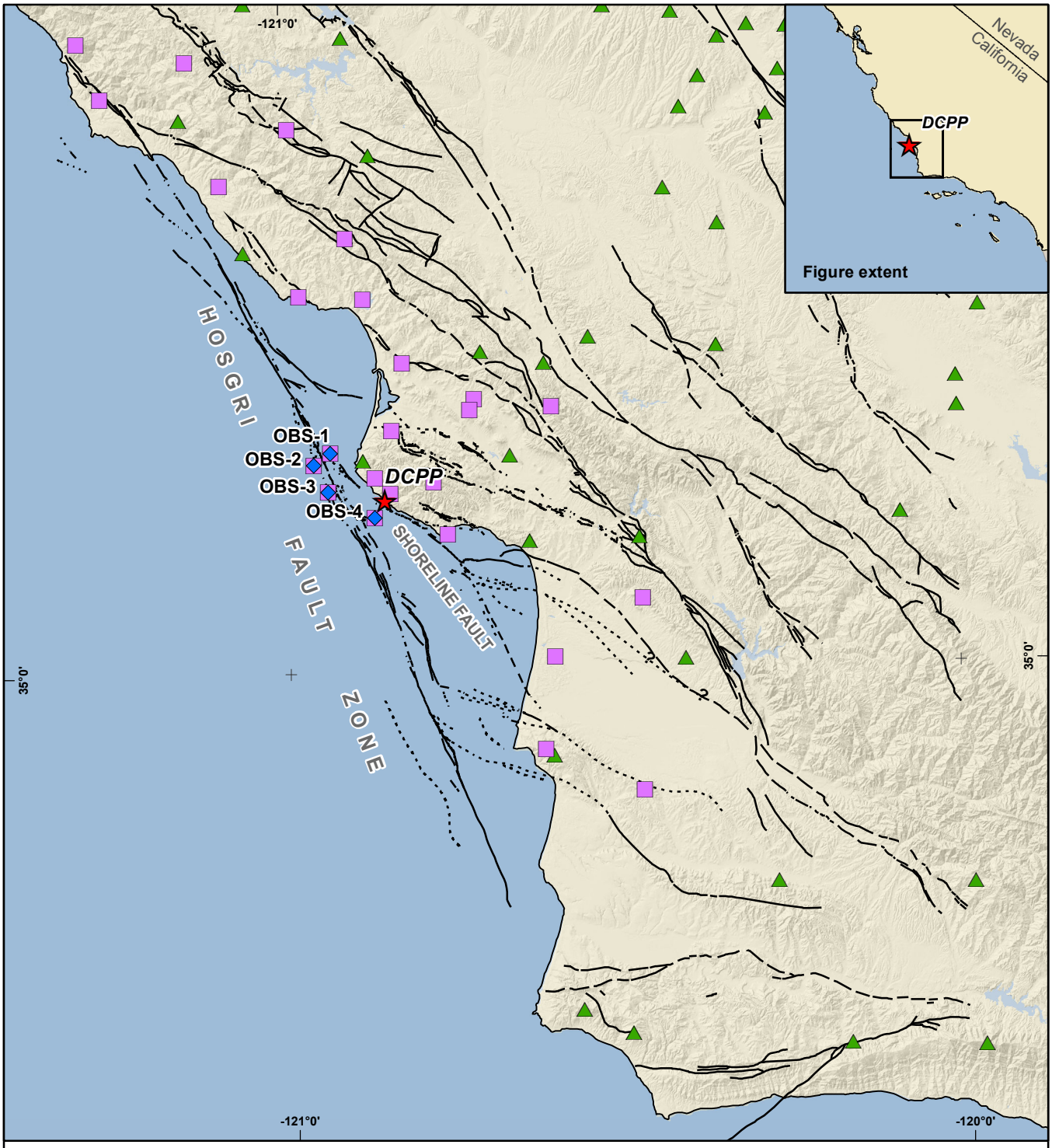


EXPLANATION

- USGS stations
- Central Coast Seismic Network
- Long-term OBS locations
- Fault, solid where well located, dashed where approximately located, dotted where inferred, queried where existence uncertain.

N

0 10 20 mi.

0 20 40 km

Map projection and scale: WGS 84 / UTM Zone 10N, 1:800,000

Central Coast Region Seismic Networks

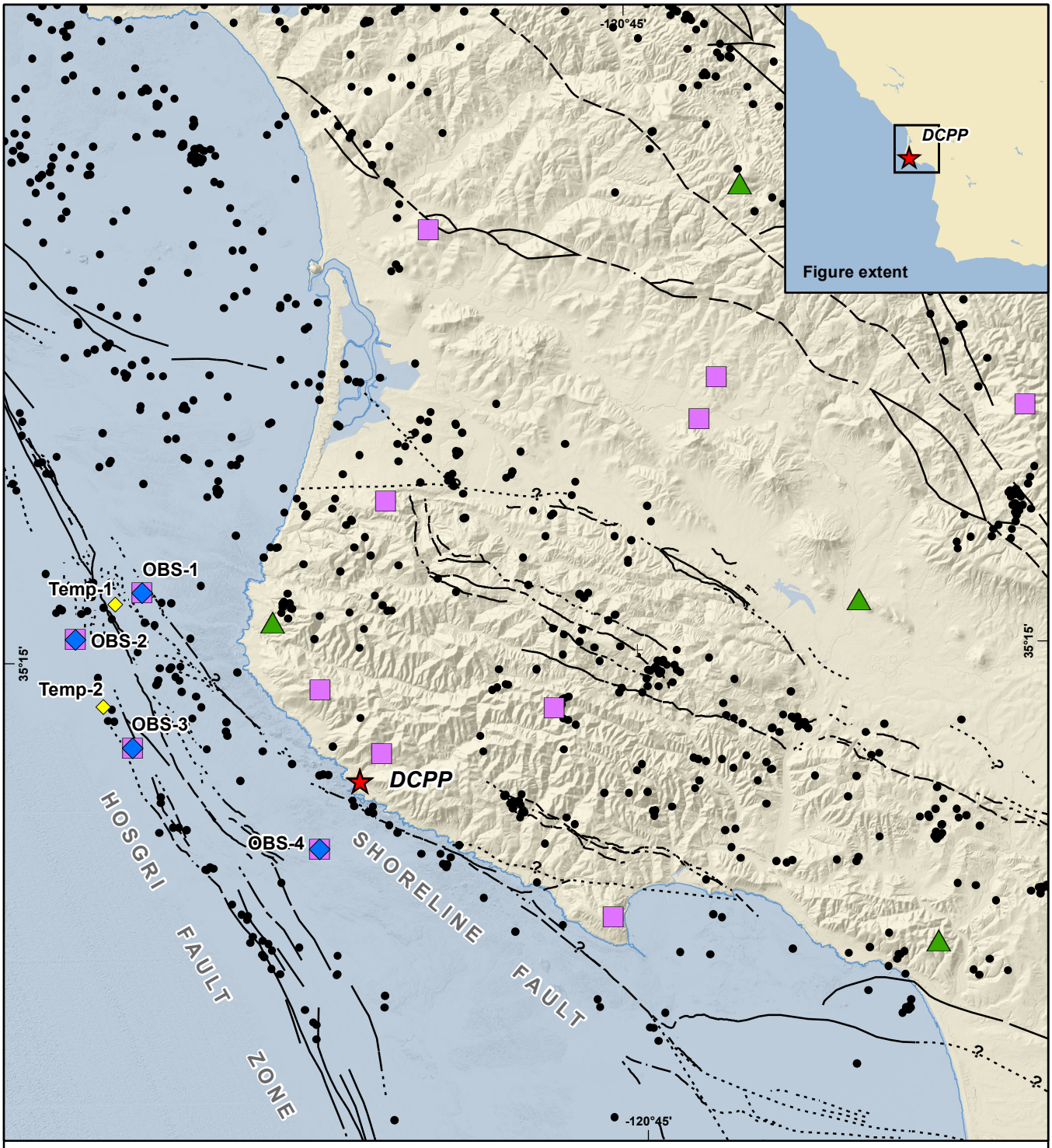
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **1-1**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_1-01.mxd; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1



EXPLANATION

- USGS stations
- Central Coast Seismic Network
- Long-term OBS locations
- Temporary OBS locations
- Seismicity (J. Hardebeck, pers. comm., 2014)
- Fault, solid where well located, dashed where approximately located, dotted where inferred, queried where existence uncertain.

N

0 2 4 mi.

0 4 8 km

Map projection and scale: WGS 84 / UTM Zone 10N, 1:200,000

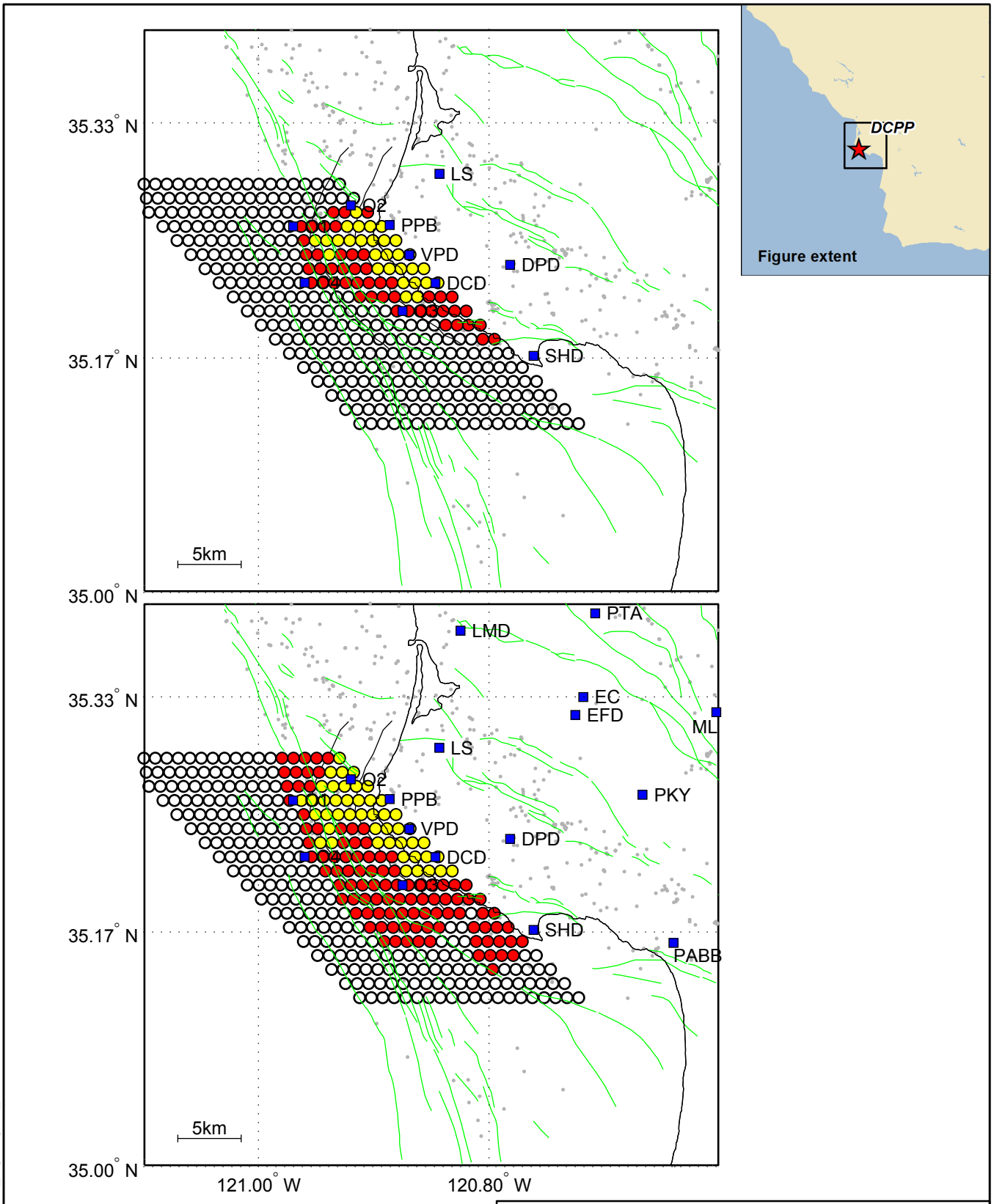
OBS and On-Land Seismic Stations with Seismicity

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **1-2**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_1-02.mxd; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1



Notes:
- Synthetic events recorded at stations within 20 km (top) and 55 km (bottom).
- Blue squares are OBS locations.
- Red and yellow circles indicate good and better location results, respectively, based on network criteria defined in Sensitivity Analysis (Appendix A).

Sensitivity Analyses for Optimum OBS Station Locations

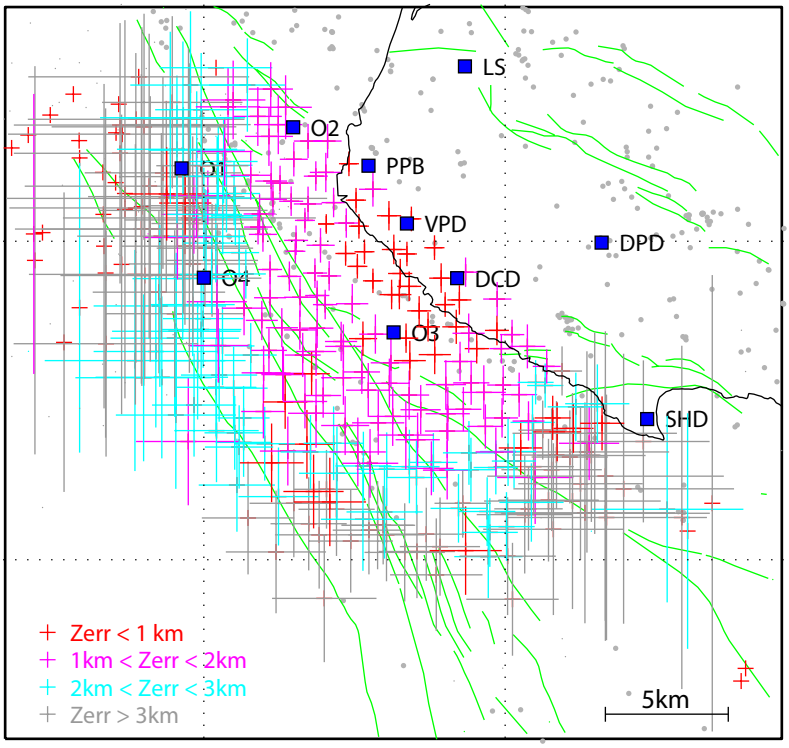
POINT BUCHON OBS PROJECT

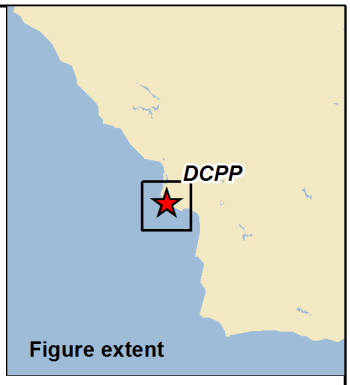
Pacific Gas and Electric Company

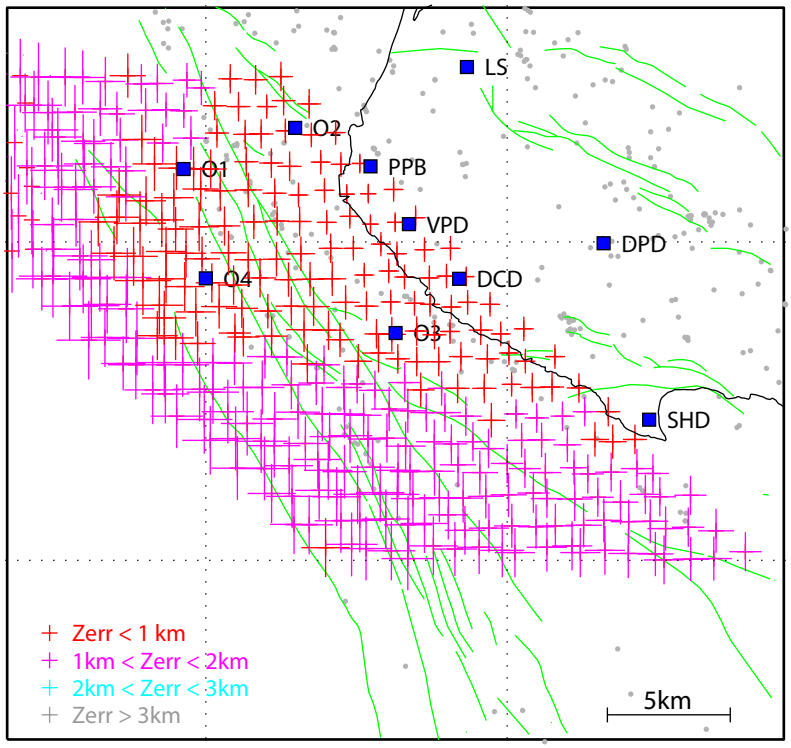
Figure **2-1**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_2-01.ai; Date: 05/14/2014; User: Alex Remar, LCI; Rev.1







Note: Locations and corresponding errors from HYPOINVERSE for synthetic events recorded at stations within 20 km (top) and 55 km (bottom). Size of '+' represents lateral errors; vertical errors are color coded. Stations are represented by blue squares.

Sensitivity Analyses: Location and Error Results Using Synthetic Event Locations

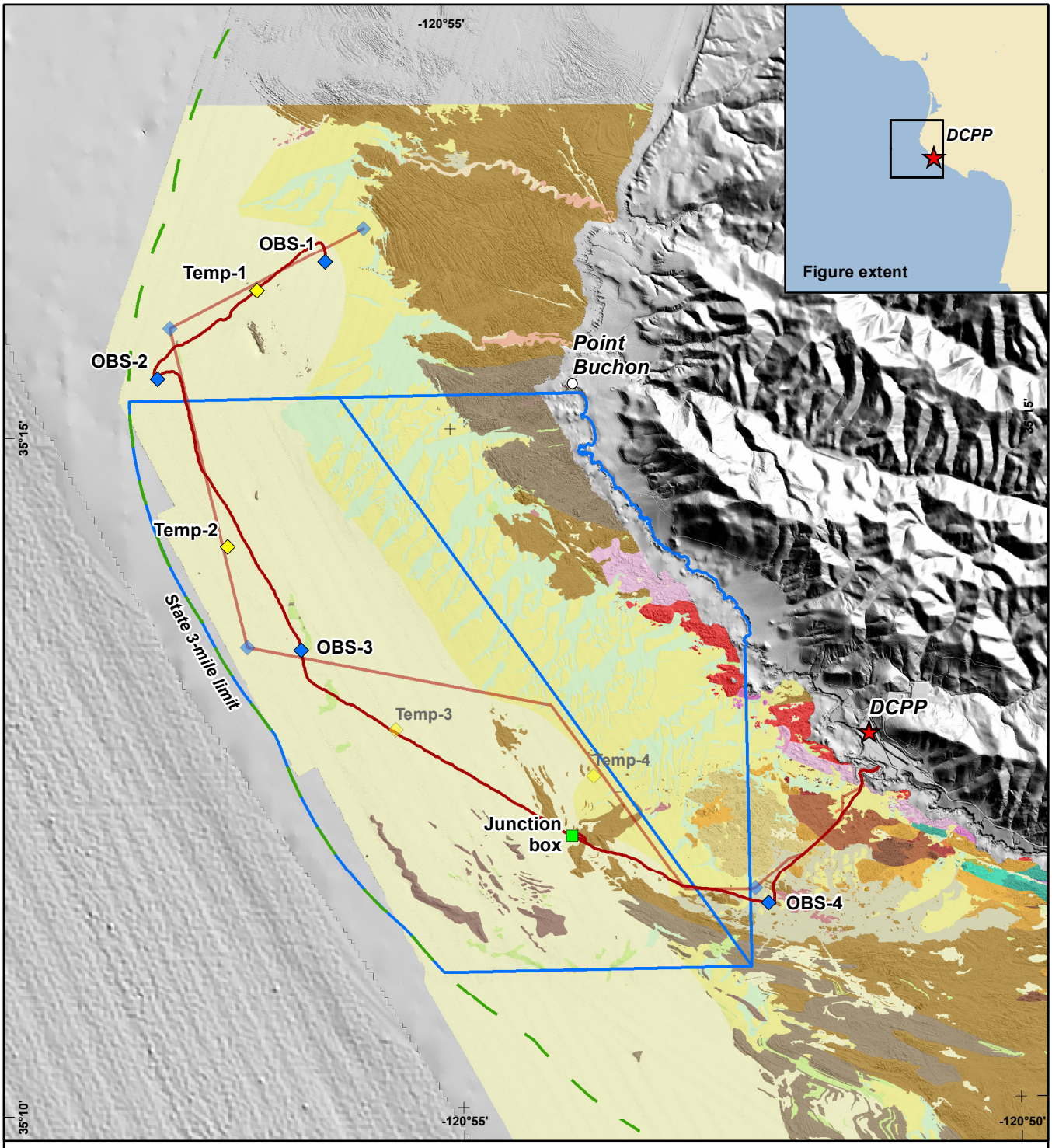
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **2-2**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_2-02.ai; Date: 05/14/2014; User: Alex Remar, LCI; Rev.1



EXPLANATION

Surveyed Station Locations

- Long-term OBS locations
- Temporary OBS locations
- OBS cable route

Original Planned Station Locations

- Long-term OBS locations
- Temporary OBS locations
- OBS cable route

Habitat mapping

- Soft sediments
- Hard sediments
- Hard diabase & resistant tuff
- Mixed hard/soft sediment covered bedrock

Boundaries

- State 3-mile limit
- Marine Protected Area

Source: State 3-mile limit and Marine Protected Area data downloaded from California Department of Fish and Wildlife website (www.dfg.ca.gov).

N

0 1 2 mi.

0 2 4 km

Map projection and scale: WGS 84 / UTM Zone 10N, 1:80,000

Seafloor Habitats with Installed OBS and Cable Locations, Marine Protected Area, and Original Planned OBS and Cable Locations Shown in Faded Colors

POINT BUCHON OBS PROJECT

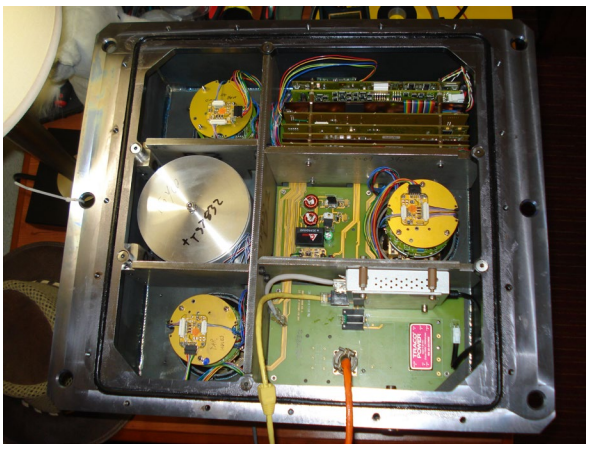
Pacific Gas and Electric Company

Figure **2-3**

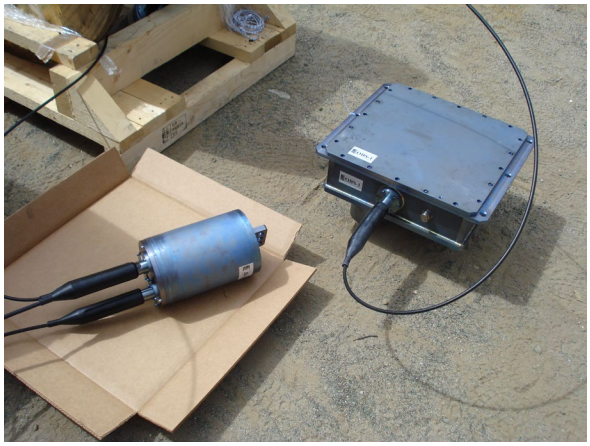
Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_2-03.mxd; Date: 09/03/2014; User: Alex Remar, LCI; Rev.1

(a) Cable containing optical fiber for two-way data transmission and power from shore to the units



(b) Instruments inside stainless steel box



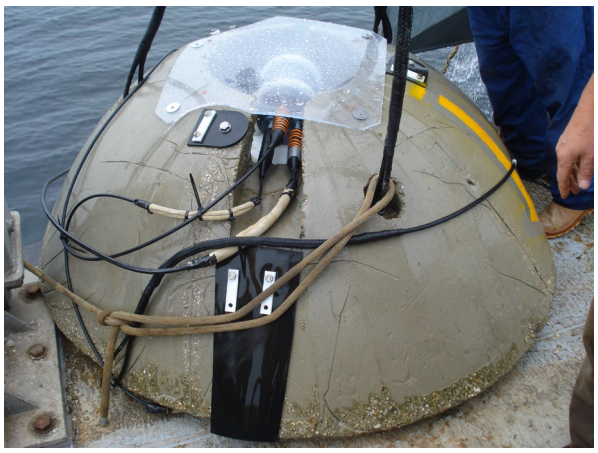
(c) Titanium box encloses the instruments; junction box (cylinder) connects cables to each OBS

(d) Instruments protected by concrete caps (each measures 1 foot high and 6 feet across and weighs 1 ton)

OBS Instrumentation

POINT BUCHON OBS PROJECT

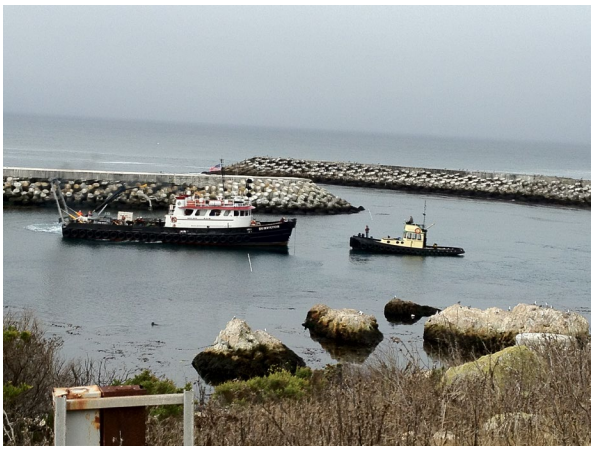
Pacific Gas and Electric Company | Figure **2-4**



(a) OBS ready for deployment

(b) OBS and cable deployed off the stern

(c) Schematic of cable in DCPP intake (yellow line) to onshore recording center (yellow circle)



(d) *Surveyor* (large boat) lays cable in intake. Tugboat stays between boat and intake structure on the right (not shown)

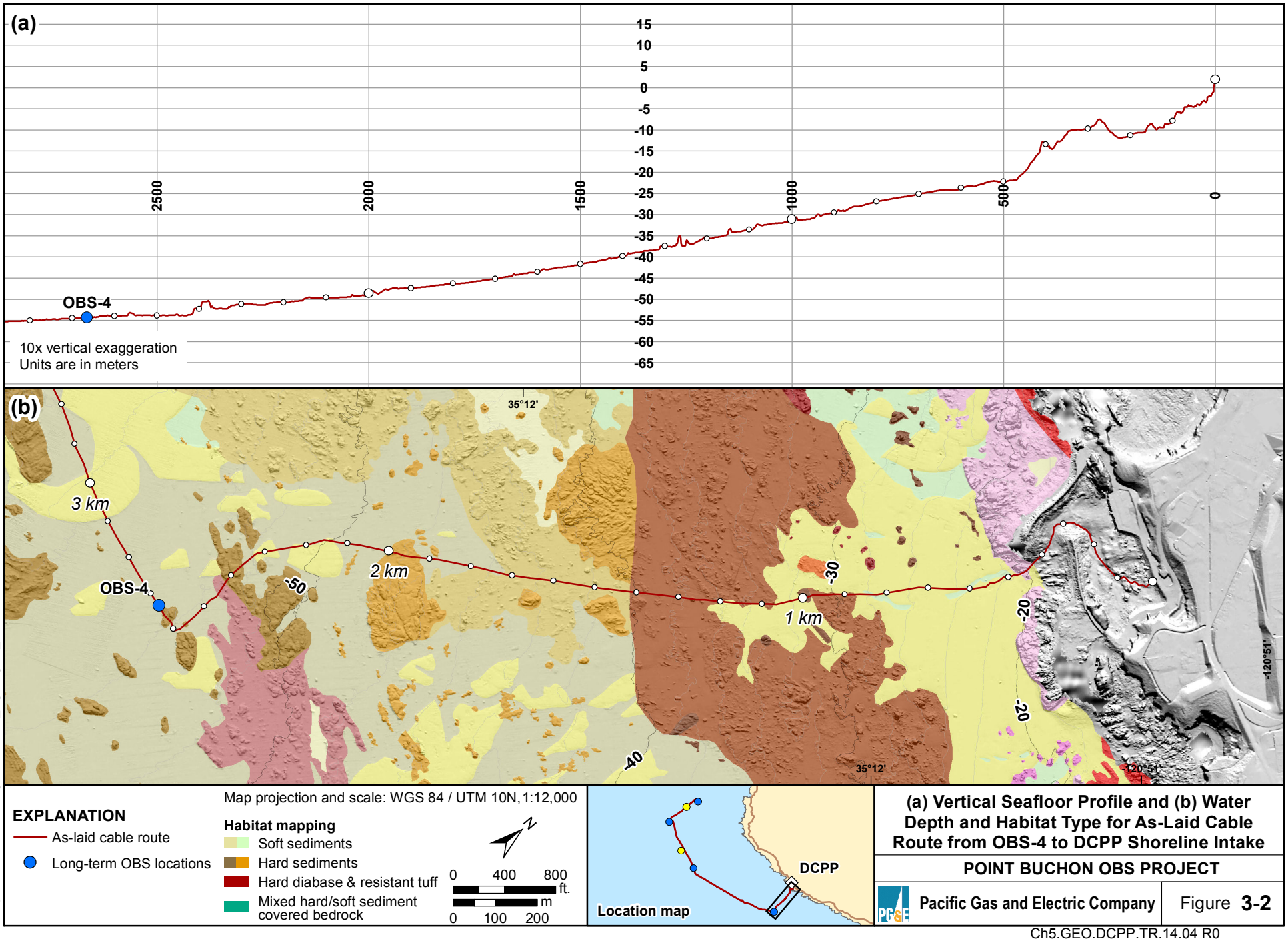
OBS Deployment

POINT BUCHON OBS PROJECT

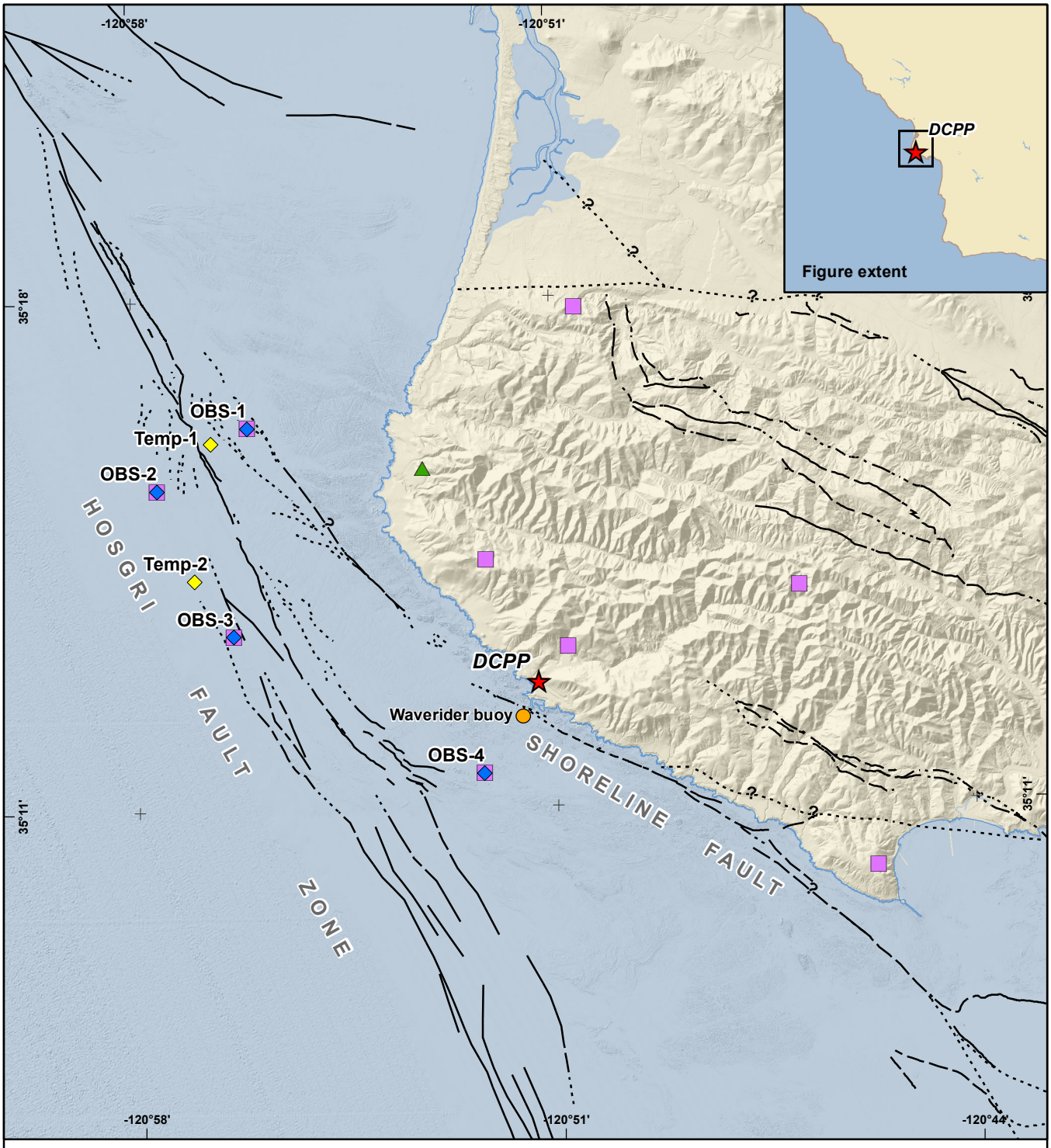
Pacific Gas and Electric Company | Figure **3-1**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_3-01.ai; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1



Ch5.GEO.DCPP.TR.14.04 R0



EXPLANATION

- USGS stations
- Temporary OBS locations
- Central Coast Seismic Network
- Long-term OBS locations
- Waverider buoy
- Fault, solid where well located, dashed where approximately located, dotted where inferred, queried where existence uncertain.

N

0 2 4 mi.

0 4 8 km

Map projection and scale: WGS 84 / UTM Zone 10N, 1:150,000

Noise Survey: OBS Location Relative to the Waverider Buoy

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **4-1**

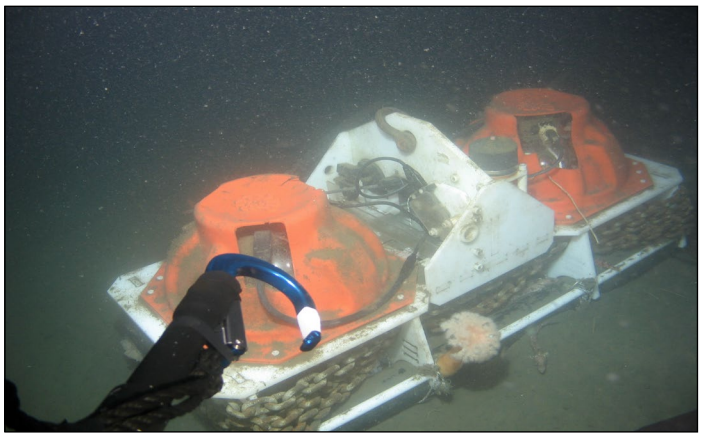
Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_4-01.mxd; Date: 06/18/2014; User: Alex Remar, LCI; Rev.1

(a) Instruments in pre-deployment configuration. Instruments are covered with orange plastic protectors.

(b) Cement ballasts with the sensor mounted in the center underneath the frames.

(c) One of the temporary OBS units shortly before deployment. Chains were added to increase the stability of the unit.

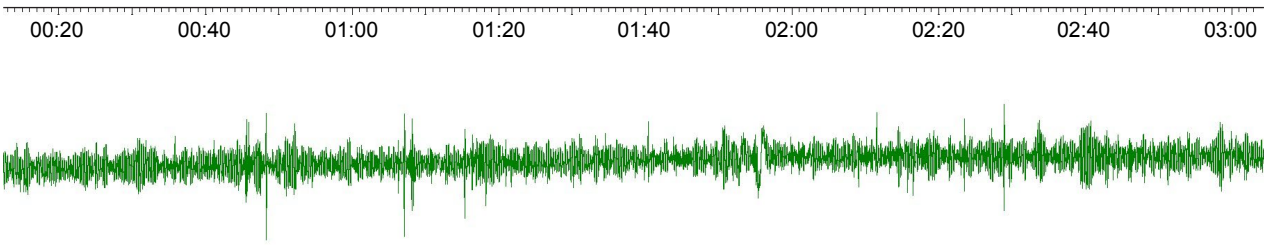


(d) Temporary Unit 2 on the seafloor shortly before recovery, after 106 days on the ocean floor. Blue hook in the foreground is attached to the ROV manipulator and used to hook into the shackle of the frame.

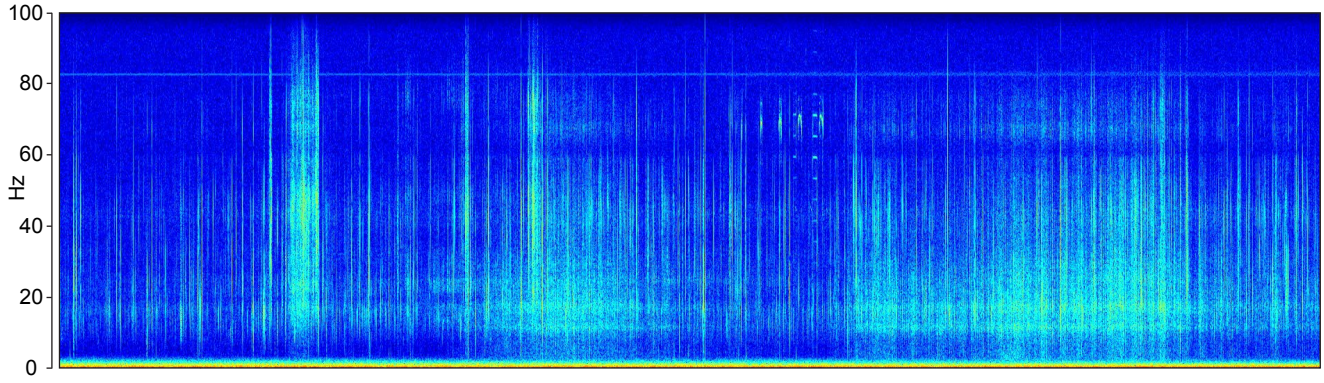
Noise Survey:
Temporary OBS Units

POINT BUCHON OBS PROJECT

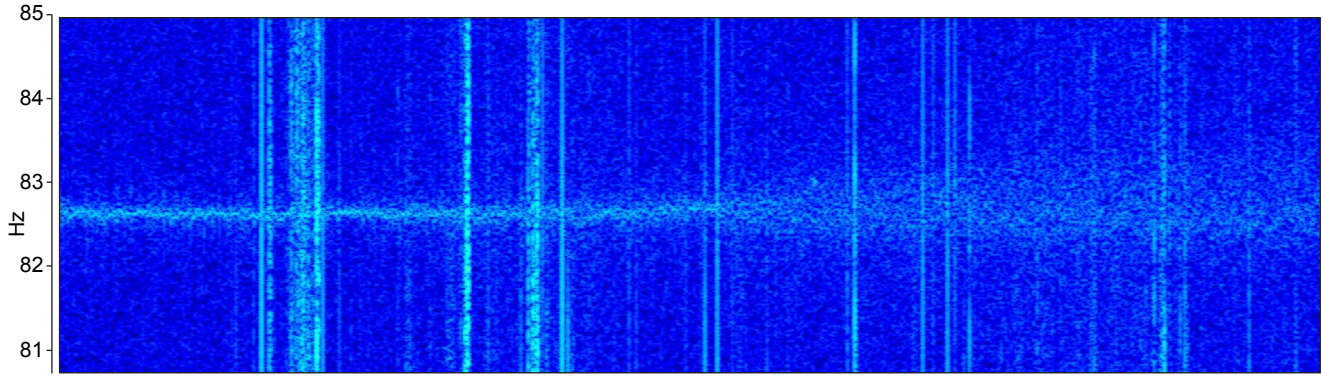
Pacific Gas and Electric Company | Figure **4-2**



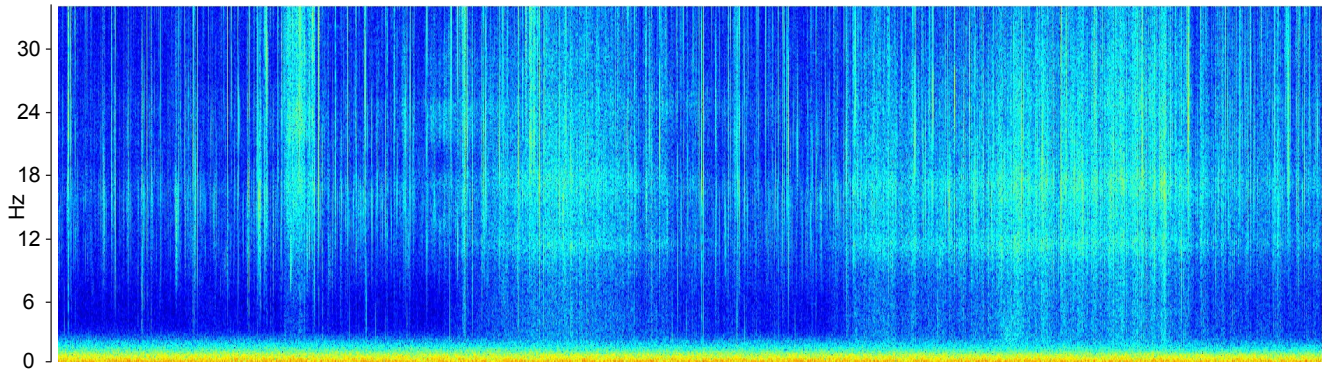
(a) Temp-2 time history series



(b) Spectrogram of the noise recording showing amplitudes in the frequency band to 100 Hz



(c) Spectrogram in the frequency band between 80.5 and 85 Hz



(d) Spectrogram in the frequency band up to 33 Hz

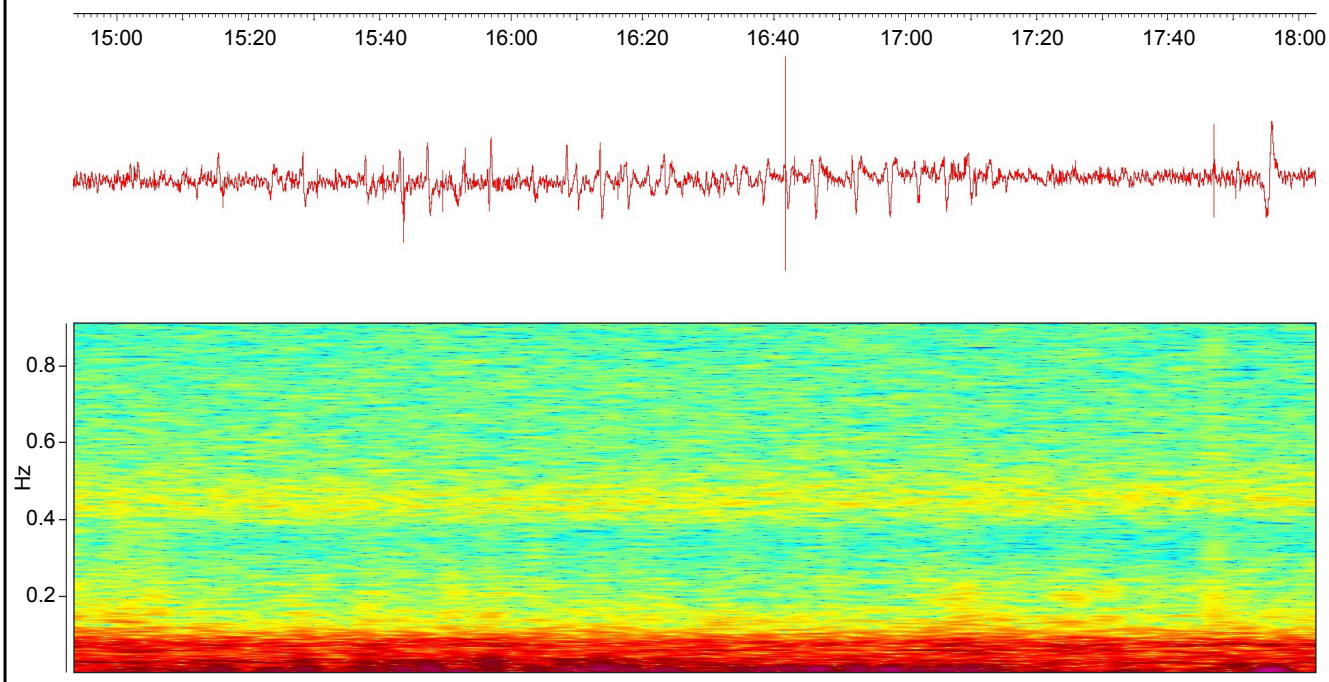
Note: Recorded on 15 Oct 2013, 00:20 to 03:00 UTC.

Noise Survey:
Short-Period Noise
Recorded on Temp-2

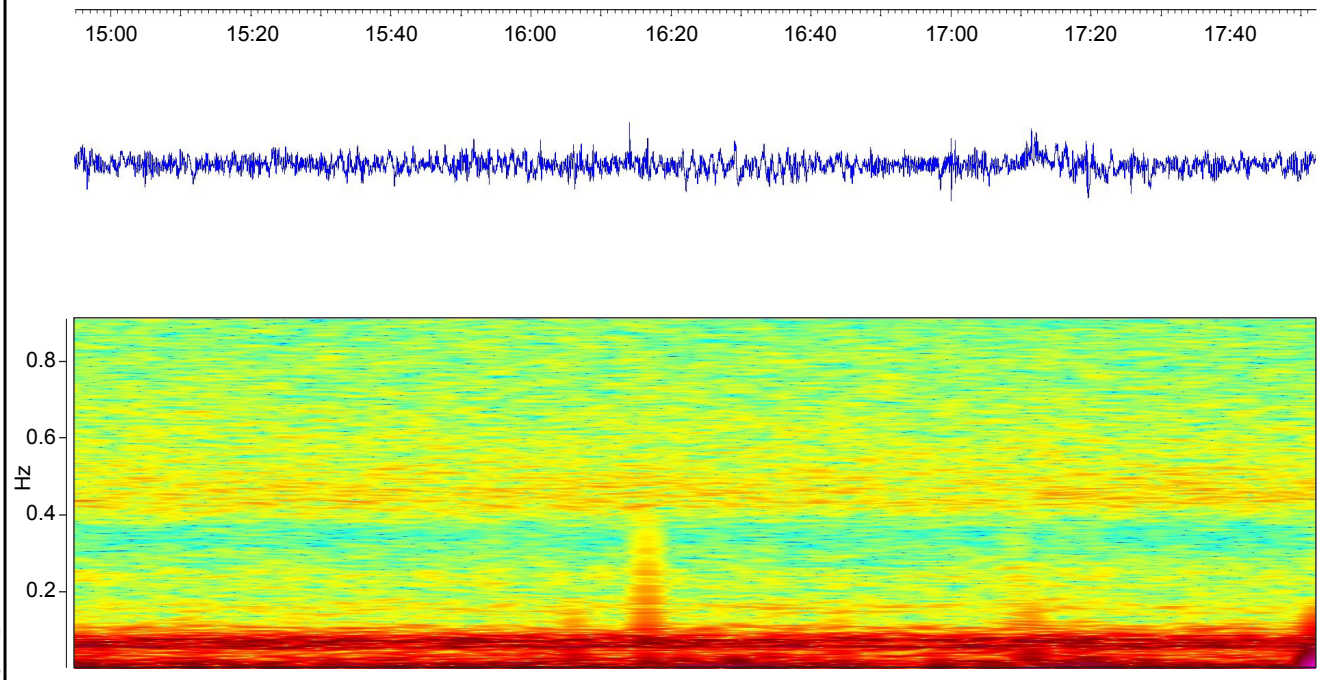
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **4-3**



(a) Temp-1 horizontal component; time series (top) spectrogram (bottom)



(b) Temp-2 horizontal component; time series (top) spectrogram (bottom)

Note: Recorded on 8 Aug 2013, 15:00 to 18:00 UTC.

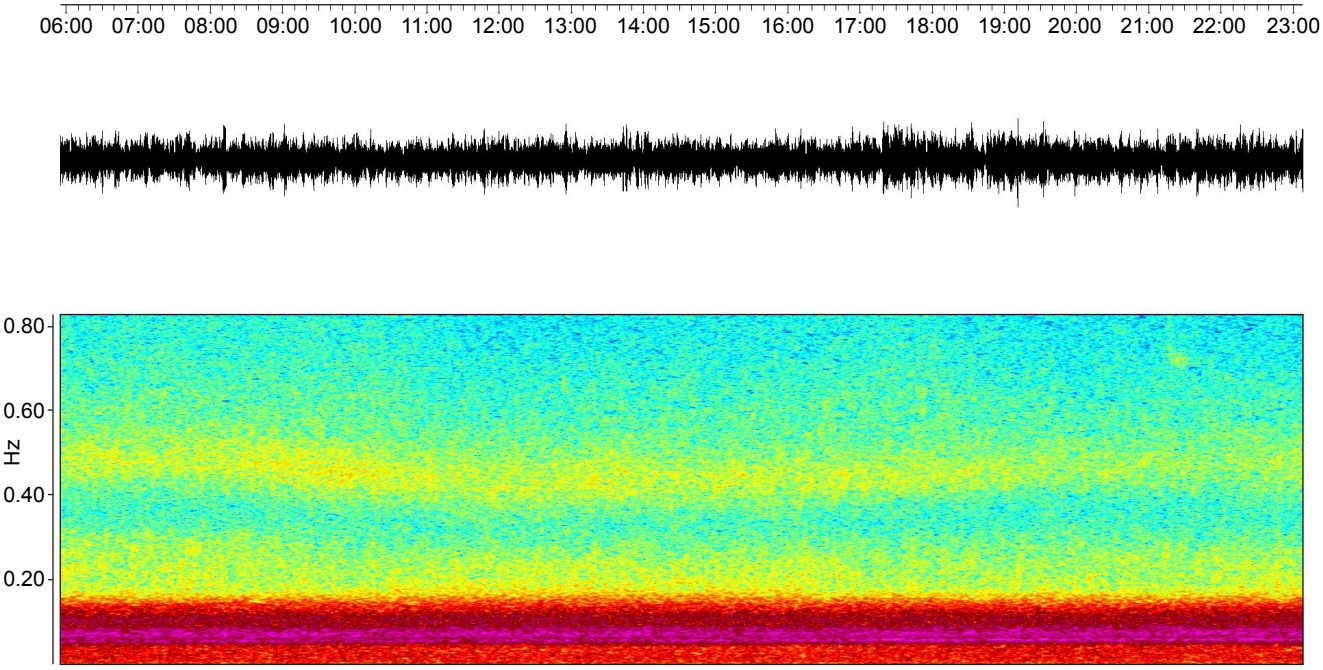
Noise Survey:
Long-Period Noise
Recorded on Temp-1 and Temp-2

POINT BUCHON OBS PROJECT

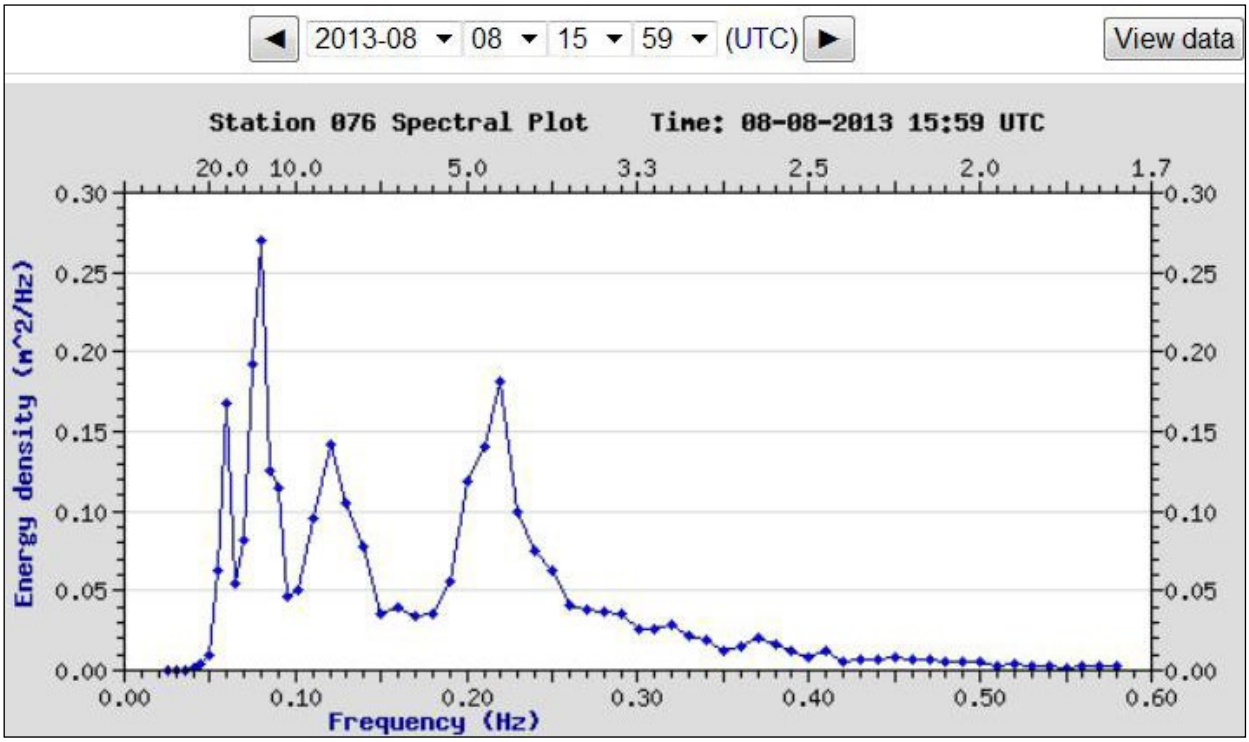
Pacific Gas and Electric Company | Figure **4-4**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_4-04.ai; Date: 05/14/2014; User: Alex Remar, LCI; Rev.1



(a) Time series (black lines) and spectrogram (colored band) from the DPG recording on 15 Aug 2013 between 5:30 and 23:00 UTC



(b) Energy density spectrum of the ocean waves as measured by the waverider buoy 076 on 15 Aug 2013 at approximately 16:00 UTC

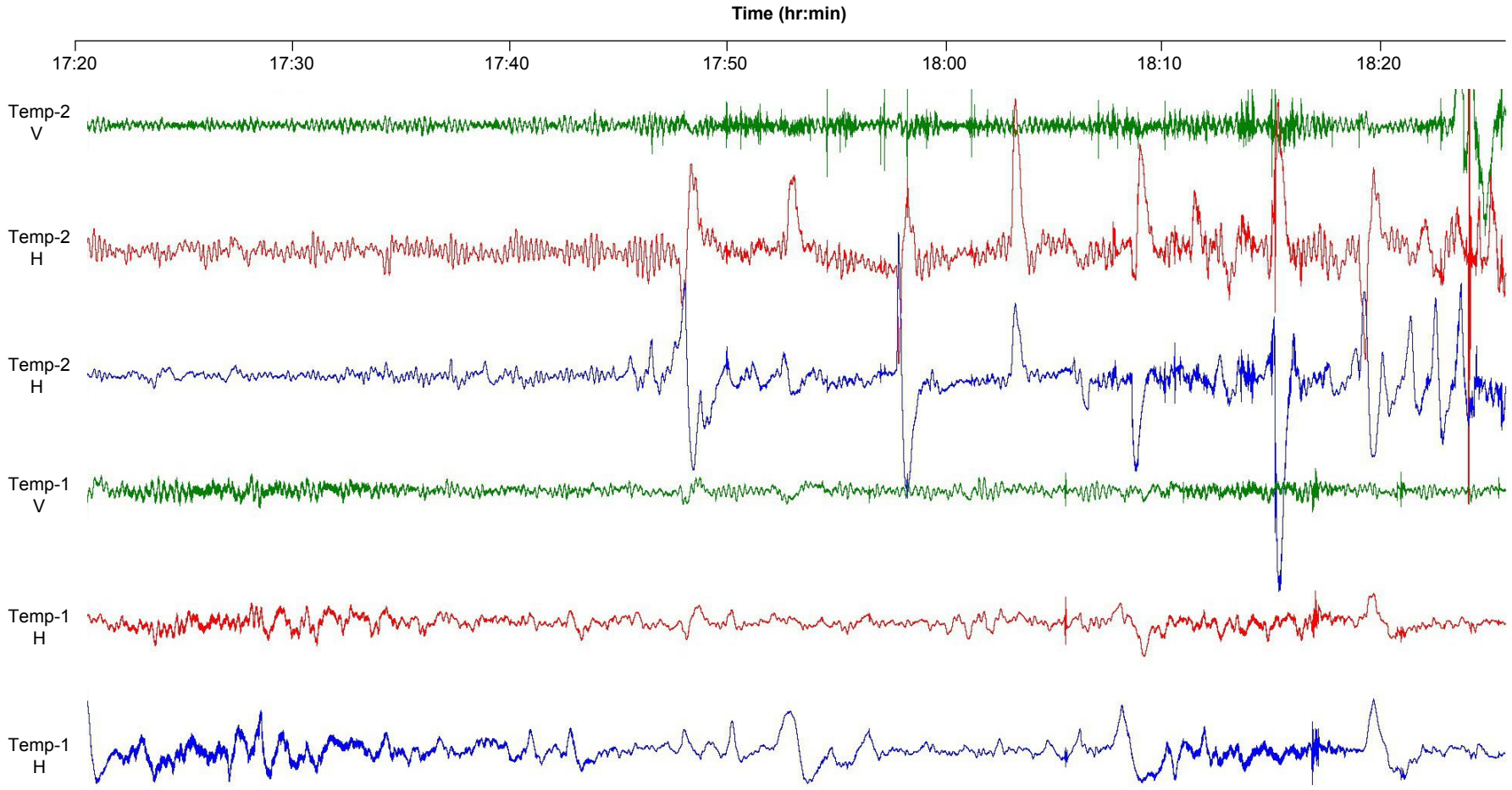
Noise Survey:
DPG Recording and Spectrogram

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-5**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_5-06.ai; Date: 05/14/2014; User: Alex Remar, LCI; Rev.1



Note: Recordings during a 70-minute time window on 23 Aug 2013 from 17:20 to approximately 18:30 UTC. Top three traces are the three components of Temp-2, bottom three are of Temp-1.

V = Vertical component
H = Horizontal component

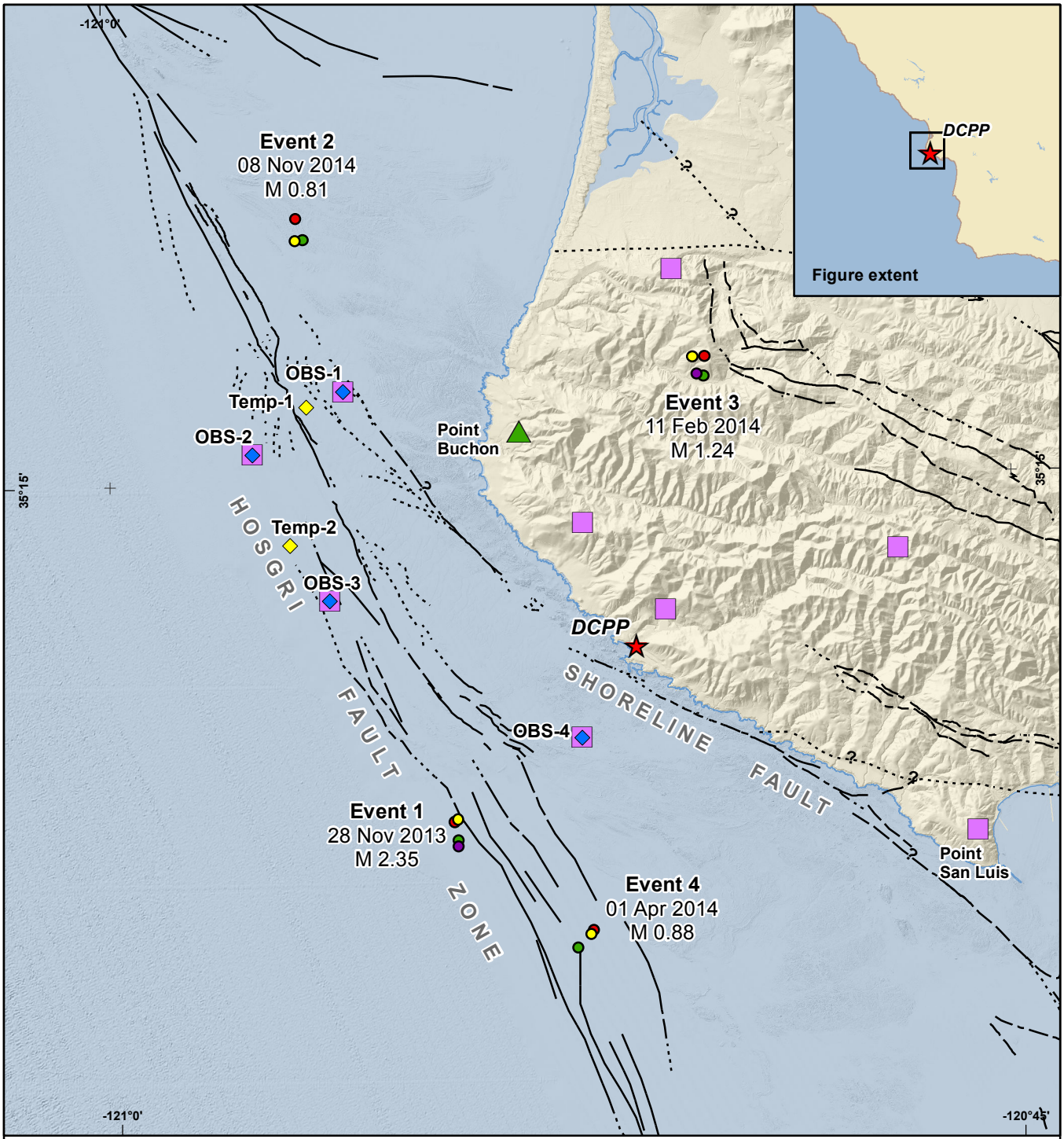
Noise Survey:
Example of Artificial Noise
from Temp-1 vs. Temp-2 Recordings

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-6**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_4-06; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1



EXPLANATION

- USGS stations
- Temporary OBS locations
- Central Coast Seismic Network
- Long-term OBS locations

Earthquake Location Analysis Results

- (Original) USGS catalog with OBS, USGS velocity model
- (Test 1) USGS catalog with OBS, PG&E velocity model
- (Test 2) USGS catalog, no OBS, PG&E velocity model
- (Test 3) USGS catalog with added OBS S-wave picks from PG&E, USGS velocity model

—?— Fault, solid where well located, dashed where approximately located, dotted where inferred, queried where existence uncertain.

Note: Event numbers correspond to Table 4-1.

N

0 2 4 mi.

0 4 8 km

Map projection and scale: WGS 84 / UTM Zone 10N, 1:150,000

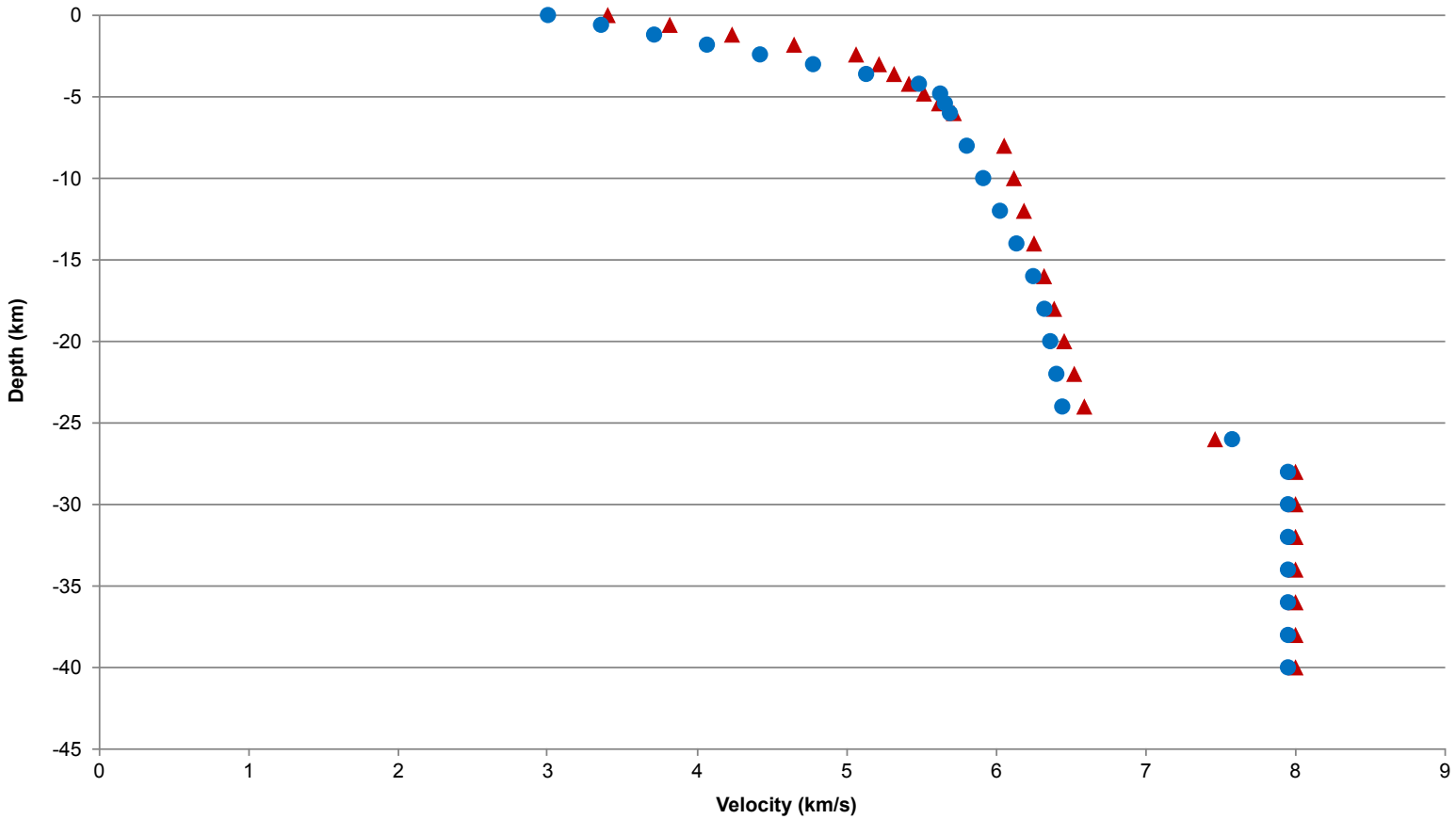
Earthquake Location Study Using OBS Recorded Data

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure 4-7

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_4-07.mxd; Date: 06/18/2014; User: Alex Remar, LCI; Rev.1



EXPLANATION

▲ USGS Model ● PG&E Model

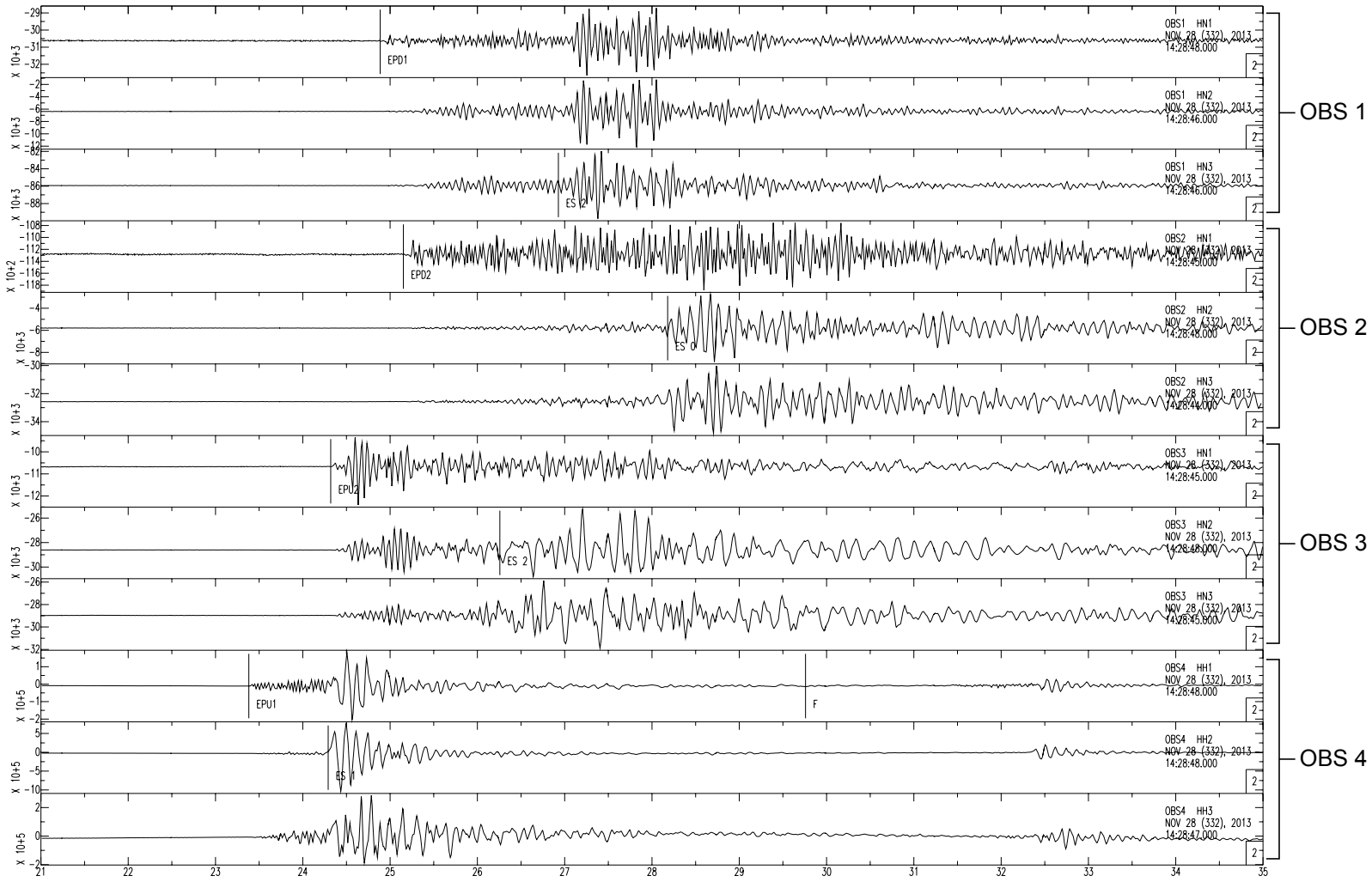
Source: USGS velocity model for the California Central Coast region from Dr. David Oppenheimer (oppen@usgs.gov).

Comparison of the USGS and PG&E CCSN Velocity Models

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-8**

Ch5.GEO.DCPP.TR.14.04 R0



Notes:
- Event 1—see Table 4-1.
- For each OBS package of three traces, the top trace is vertical and the bottom two are horizontal.
- The x-axis units are time (seconds).
- The y-axis units are volts.

OBS Recordings for the M 2.35 Earthquake on 28 Nov 2013

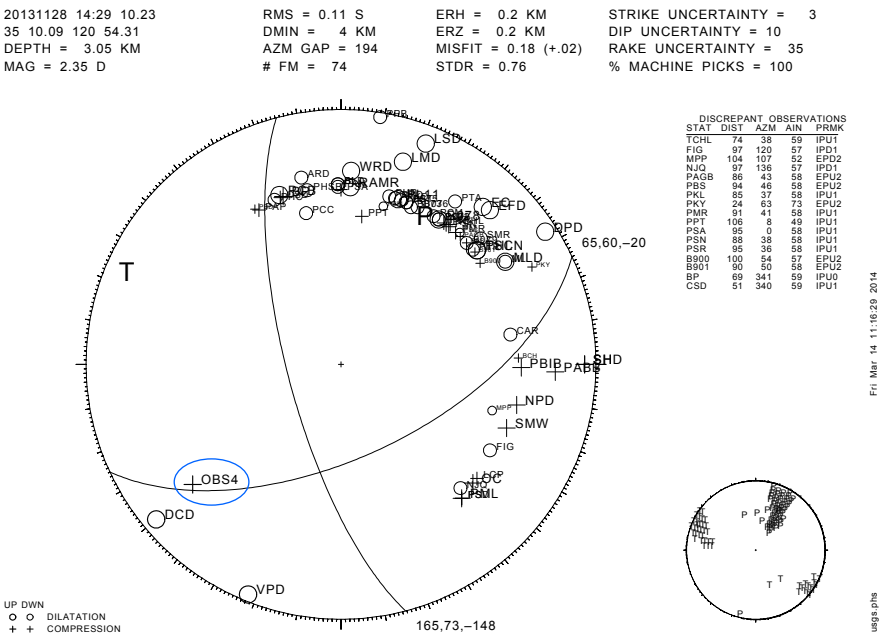
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-9**

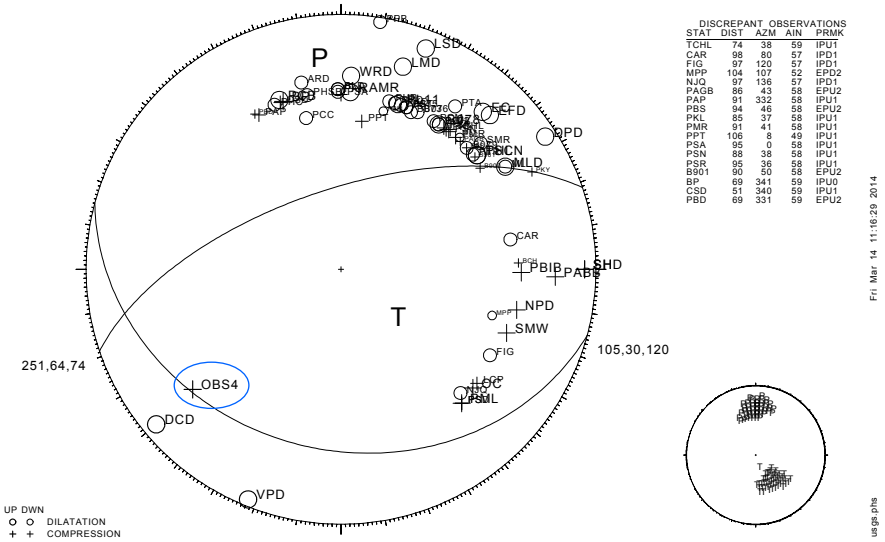
Ch5.GEO.DCPP.TR.14.04 R0

File path:S:\1005\050\Figures\Marcia_Figs\Figure_4-09.ai; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



Notes:
- Event 1—see Table 4-1 (original location) and Figure 4-7 (green circle).
- OBS first motions used in focal mechanism are circled in blue.

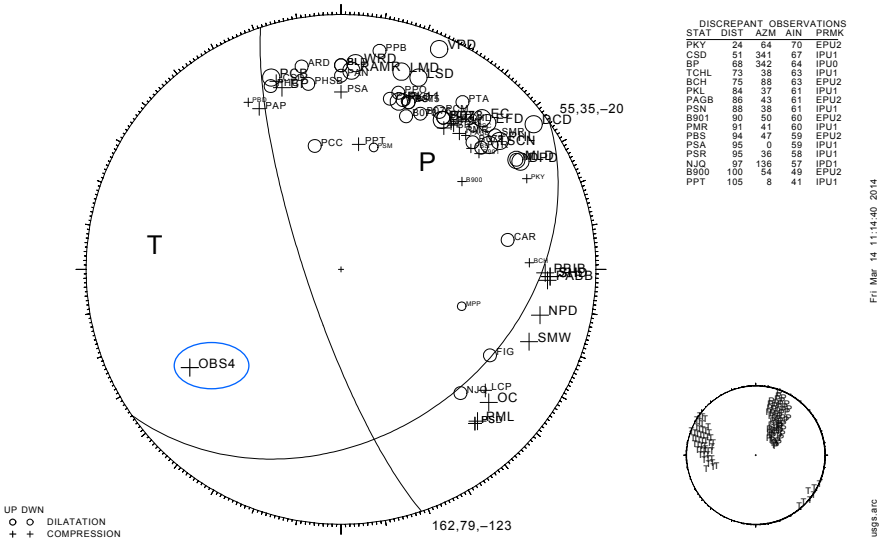
Focal Mechanisms for the M 2.35 Earthquake on 28 Nov 2013—Original NCSN Catalog Data with OBS-4 Data (USGS Velocity Model)

POINT BUCHON OBS PROJECT

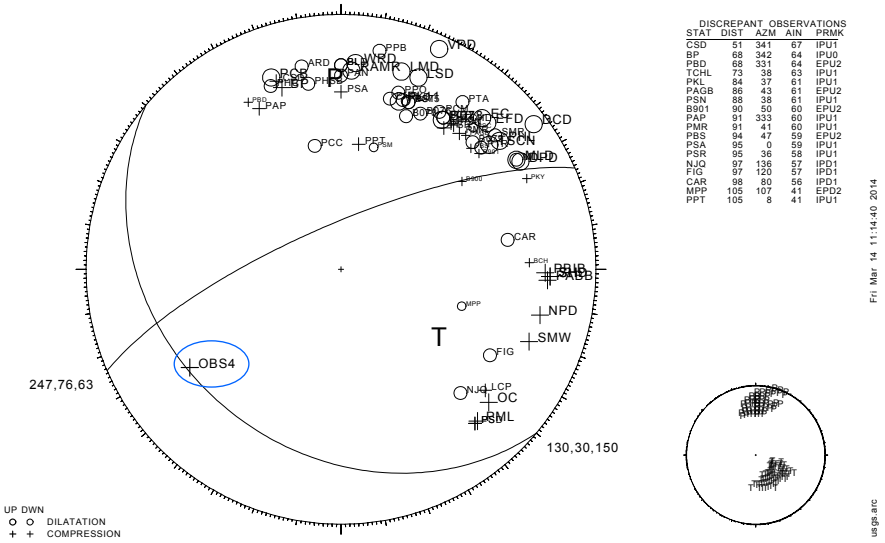
Pacific Gas and Electric Company

Figure **4-10**

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



Notes:
- Event 1—see Table 4-1 (test 1) and Figure 4-7 (red circle).
- OBS first motions used in focal mechanism are circled in blue.

Focal Mechanisms for the M 2.35 Earthquake on 28 Nov 2013—Original NCSN Catalog Data with OBS-4 Data (PG&E Velocity Model)

POINT BUCHON OBS PROJECT

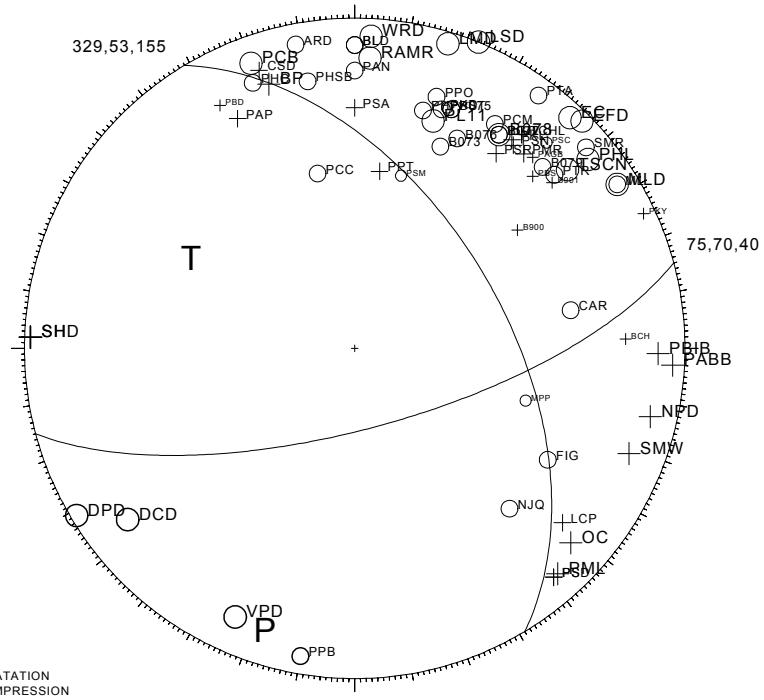
Pacific Gas and Electric Company | Figure **4-11**

20131128 14:29 10.11
35 10.38 120 54.32
DEPTH = 4.82 KM
MAG = 2.35 D

RMS = 0.12 S
DMIN = 7 KM
AZM GAP = 192
FM = 73

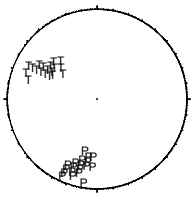
ERH = 0.3 KM
ERZ = 0.7 KM
MISFIT = 0.15 (+.02)
STDR = 0.62

STRIKE UNCERTAINTY = 10
DIP UNCERTAINTY = 10
RAKE UNCERTAINTY = 5
% MACHINE PICKS = 100



DISCREPANT OBSERVATIONS

STAT	DIST	AZM	AIN	PRMK
PKY	24	65	86	EPU2
CSD	50	341	78	IPU1
PHC	61	339	75	IPD1
TCHL	73	38	71	IPU1
PKL	84	37	68	IPU1
PAGB	86	43	68	EPU2
PSN	88	38	67	IPU1
B901	90	50	67	EPU2
PMR	91	41	67	IPU1
PBS	94	46	64	EPU2
PSA	95	0	62	IPU1
PSR	95	36	62	IPU1
B900	100	54	51	EPU2
PSM	103	15	45	EPD2
PCC	104	348	45	IPD1



Fri Mar 14 11:15:25 2014

usgsnoOBS.arc

Notes:
- Event 1—see Table 4-1 (test 2) and Figure 4-7 (yellow circle).
- Focal mechanism solution statistically fits the input first motion data.

Focal Mechanism for the M 2.35 Earthquake on 28 Nov 2013—Original NCSN Catalog Data with No OBS Data (PG&E Velocity Model)

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **4-12**

(a) Focal mechanism solution that statistically fits the input first motion data

20131128 14:29 10.26
35 10.00 120 54.31
DEPTH = 3.29 KM
MAG = 2.35 D

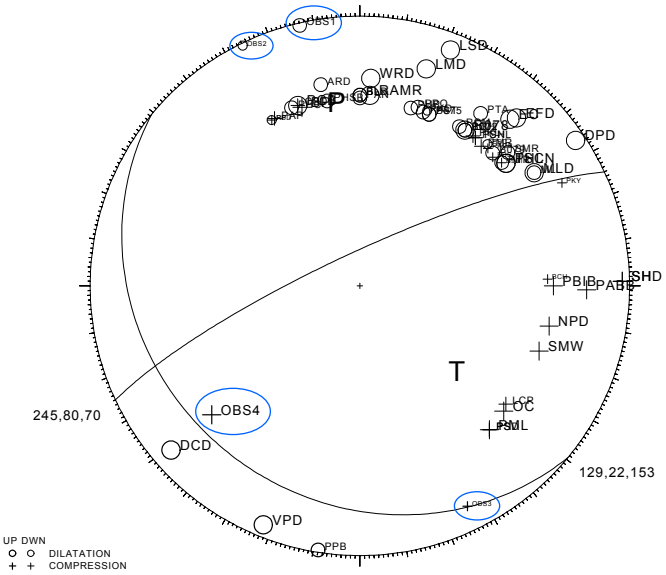
RMS = 0.15 S
DMIN = 4 KM
AZM GAP = 194
FM = 65

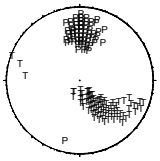
ERH = 0.2 KM
ERZ = 0.3 KM
MISFIT = 0.13 (+.03)
STDR = 0.72

STRIKE UNCERTAINTY = 13
DIP UNCERTAINTY = 13
RAKE UNCERTAINTY = 50
% MACHINE PICKS = 94

DISCREPANT OBSERVATIONS

STAT	DIST	AZM	AIN	PRMK
CSD	51	341	60	IPU1
BP	69	342	59	IPU0
PBD	69	332	59	EPU2
TCHL	74	38	59	IPU1
PKL	85	37	59	IPU1
PAGB	86	43	59	EPU2
PSN	88	38	59	IPU1
B901	90	49	59	EPU2
PAP	91	333	59	IPU1
PMR	92	41	58	IPU1
PBS	94	46	58	EPU2





Tue May 6 11:15:36 2014
merge.arc

(b) Multiple focal mechanism solution that also fits the input first motion data

20131128 14:29 10.26 (MULTIPLE)
35 10.00 120 54.31
DEPTH = 3.29 KM
MAG = 2.35 D

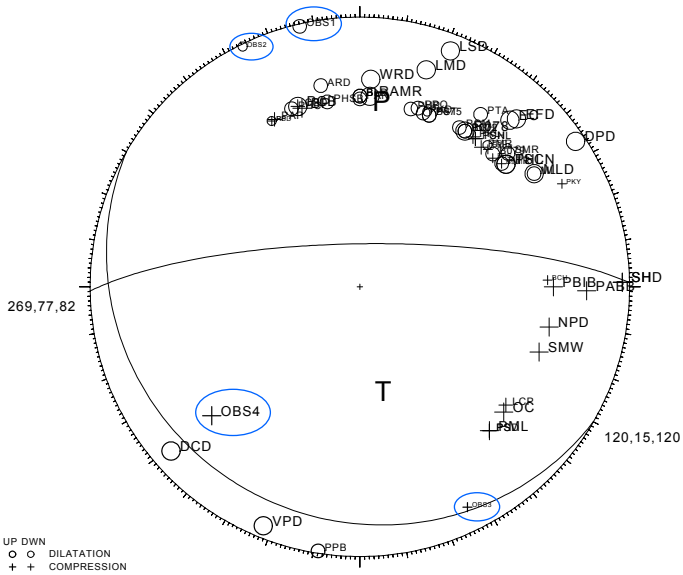
RMS = 0.15 S
DMIN = 4 KM
AZM GAP = 194
FM = 65

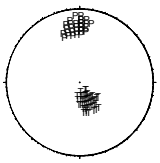
ERH = 0.2 KM
ERZ = 0.3 KM
MISFIT = 0.14 (+.03)
STDR = 0.75

STRIKE UNCERTAINTY = 13
DIP UNCERTAINTY = 8
RAKE UNCERTAINTY = 10
% MACHINE PICKS = 94

DISCREPANT OBSERVATIONS

STAT	DIST	AZM	AIN	PRMK
PKY	24	63	73	EPU2
CSD	51	341	60	IPU1
BP	69	342	59	IPU0
PBD	69	332	59	EPU2
TCHL	74	38	59	IPU1
PKL	85	37	59	IPU1
PAGB	86	43	59	EPU2
PSN	88	38	59	IPU1
B901	90	49	59	EPU2
PAP	91	333	59	IPU1
PMR	92	41	58	IPU1
PBS	94	46	58	EPU2





Tue May 6 11:15:36 2014
merge.arc

Notes:
- Event 1—see Table 4-1 (test 3) and Figure 4-7 (purple circle).
- OBS first motions used in focal mechanism are circled in blue.

Focal Mechanisms for the M 2.35 Earthquake on 28 Nov 2013—Original NCSN Catalog Data with All OBS Data (USGS Velocity Model)

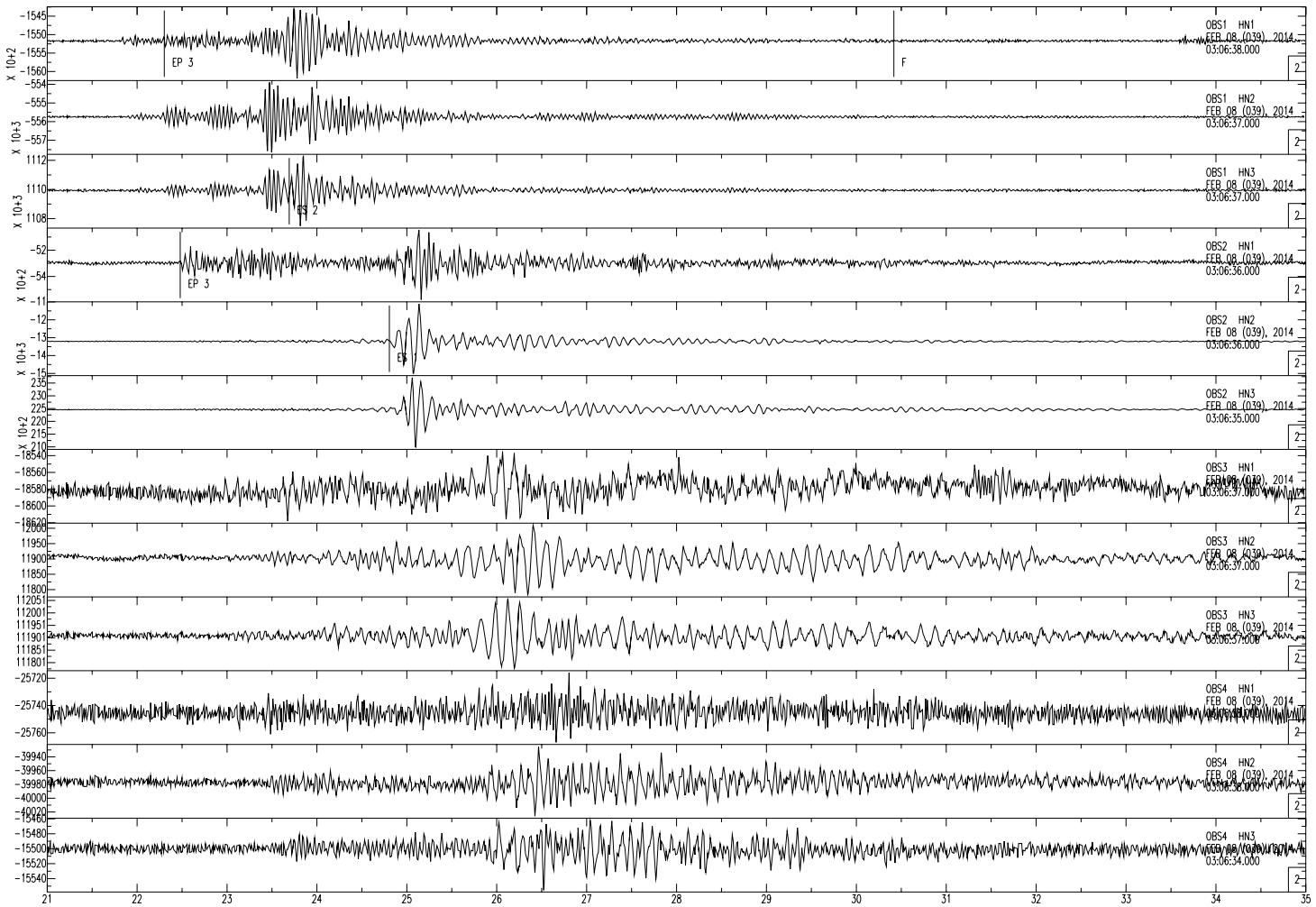
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **4-13**

Ch5.GEO.DCPP.TR.14.04 R0

File path: S:\1005\050\Figures\Marcia_Figs\Figure_4-13.ai; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1



Notes:
- Event 2—see Table 4-1.
- For each OBS package of three traces, the top trace is vertical and the bottom two are horizontal.
- The x-axis units are time (seconds).
- The y-axis units are volts.

OBS Recordings for the M 0.81 Earthquake on 08 Feb 2014

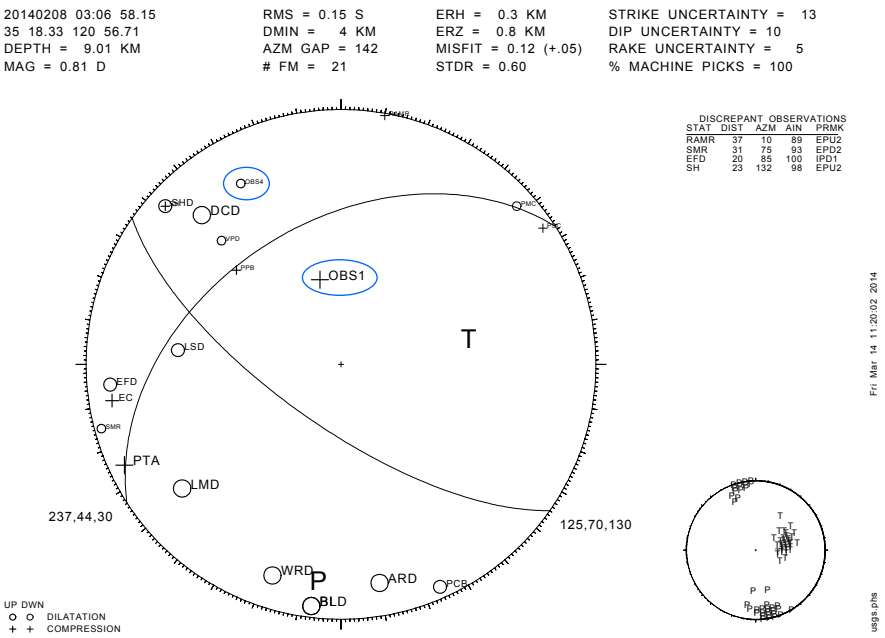
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-14**

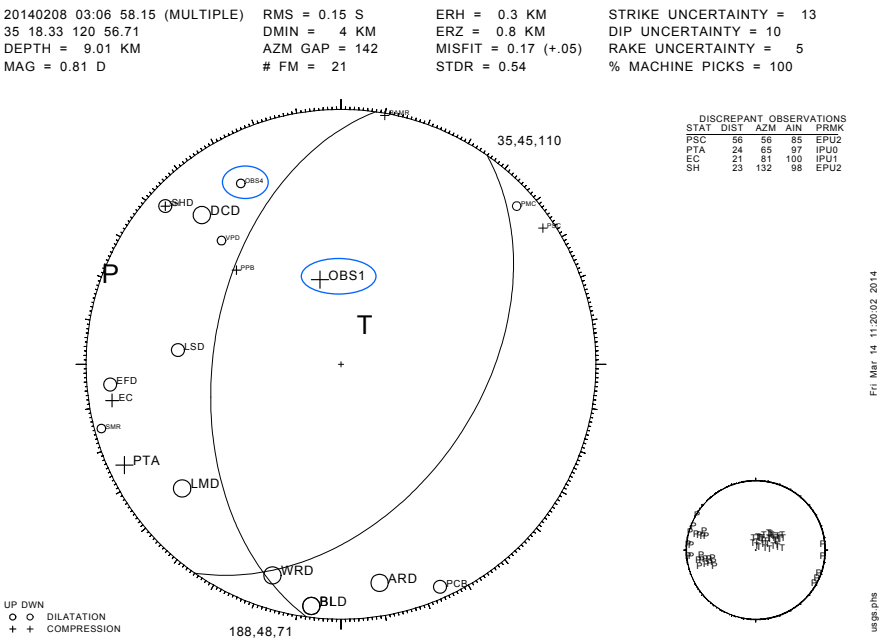
Ch5.GEO.DCPP.TR.14.04 R0

File path:S:\1005\050\Figures\Marcia_Figs\Figure_4-14.ai; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



Notes:
- Event 2—see Table 4-1 (original location) and Figure 4-7 (green circle).
- OBS first motions used in focal mechanism are circled in blue.

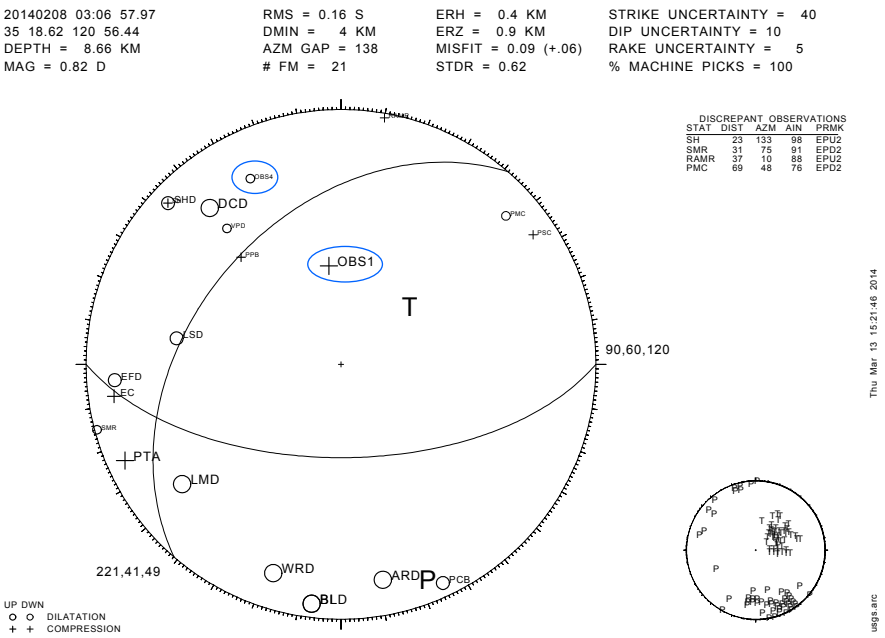
Focal Mechanisms for the M 0.81 Earthquake on 08 Feb 2014—Original NCSN Catalog Data with OBS-1 and -4 Data (USGS Velocity Model)

POINT BUCHON OBS PROJECT

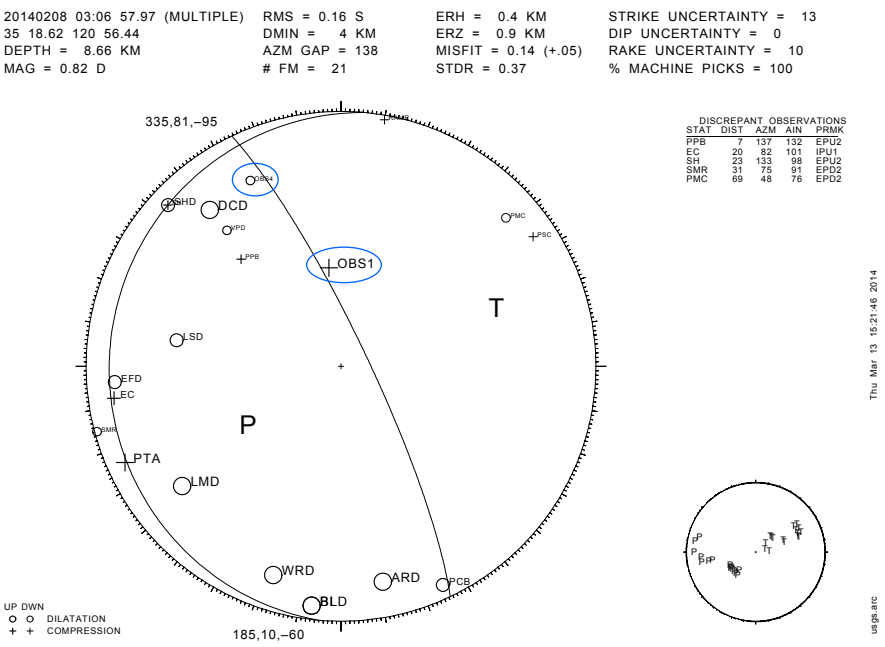
Pacific Gas and Electric Company

Figure **4-15**

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



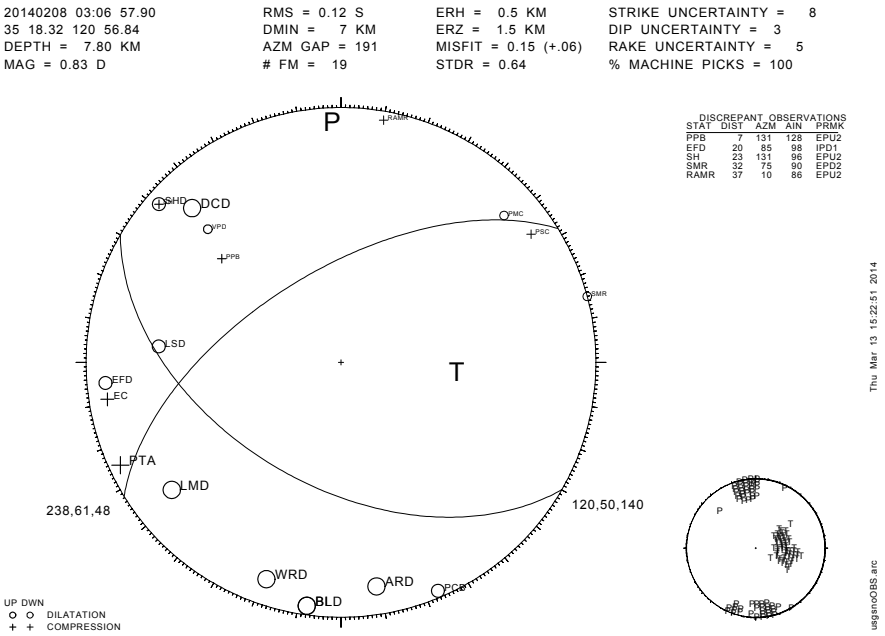
Notes:
- Event 2—see Table 4-1 (test 1) and Figure 4-7 (red circle).
- OBS first motions used in focal mechanism are circled in blue.

Focal Mechanisms for the M 0.81 Earthquake on 08 Feb 2014—Original NCSN Catalog Data with OBS-1 and -4 Data, (PG&E Velocity Model)

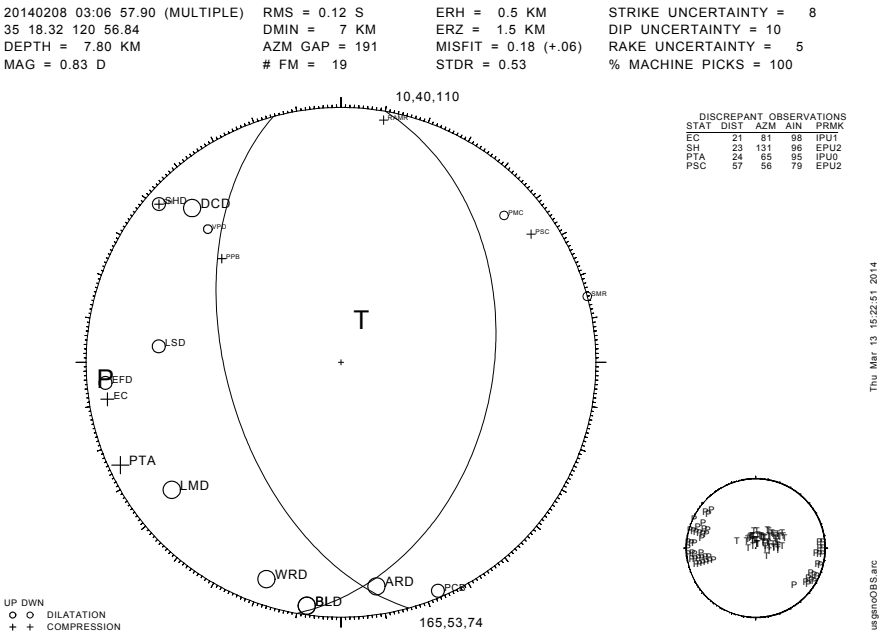
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-16**

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



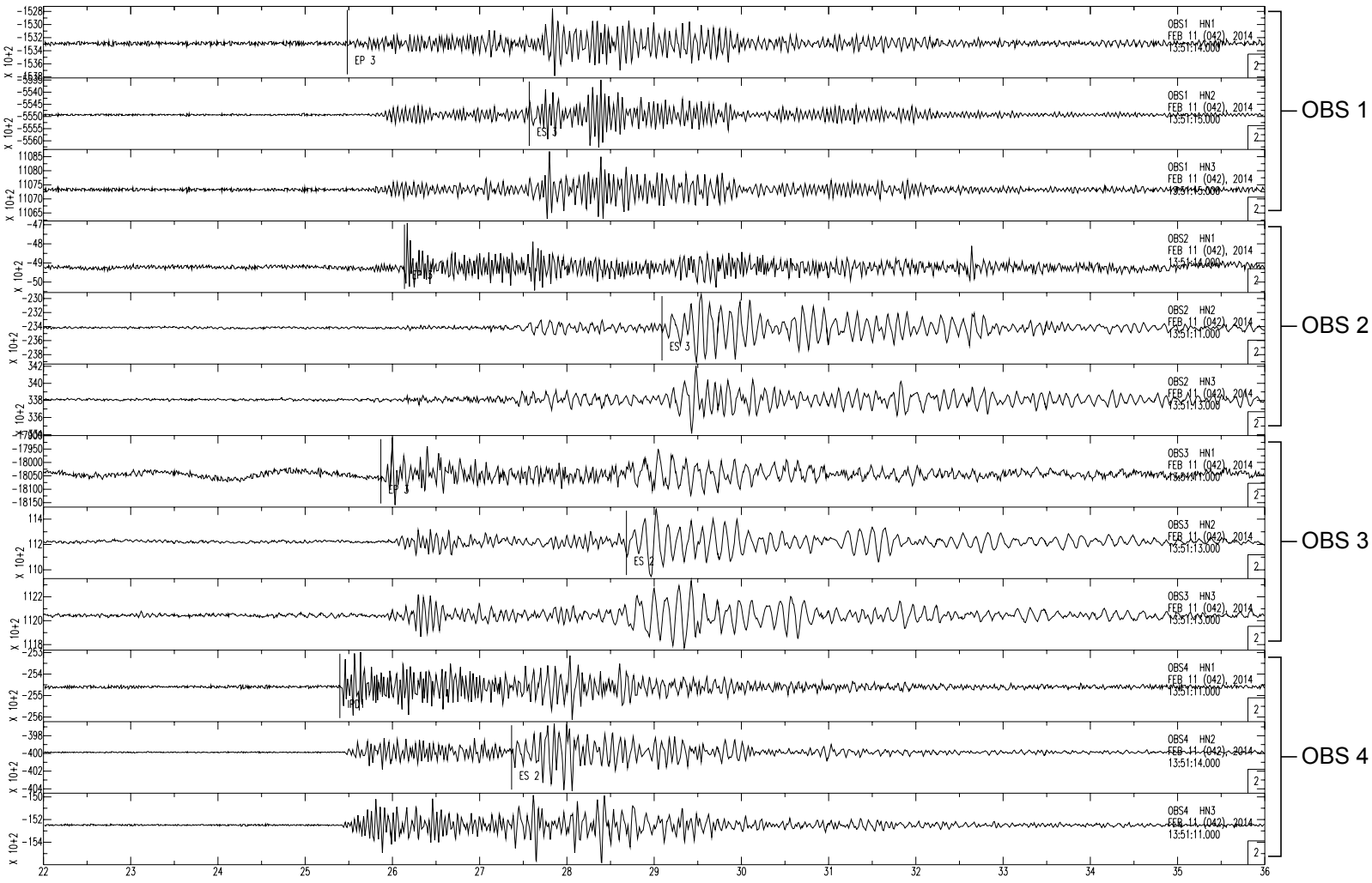
Note: Event 2—see Table 4-1 (test 2) and Figure 4-7 (yellow circle).

Focal Mechanisms for the M 0.81 Earthquake on 08 Feb 2014—Original NCSN Catalog Data with No OBS Data (PG&E Velocity Model)

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **4-17**



Notes:
- Event 3—see Table 4-1.
- For each OBS package of three traces, the top trace is vertical and the bottom two are horizontal.
- The x-axis units are time (seconds).
- The y-axis units are volts.

OBS Recordings for the M 1.24 Earthquake on 11 Feb 2014

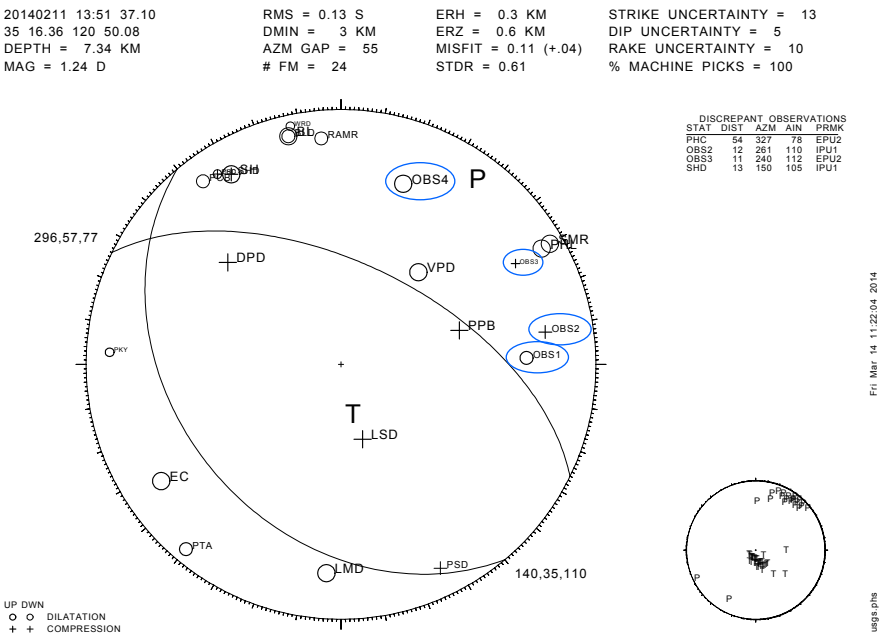
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-18**

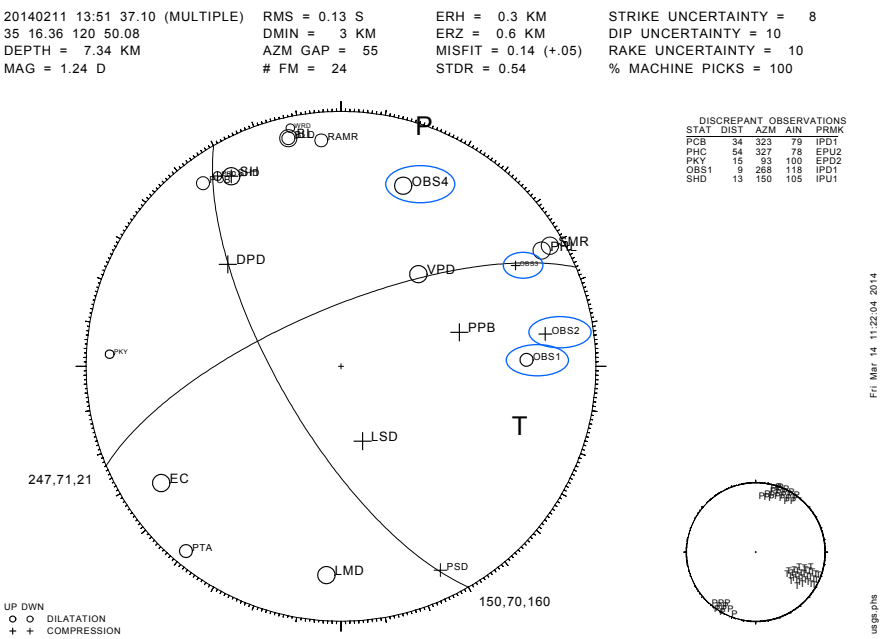
Ch5.GEO.DCPP.TR.14.04 R0

File path:S:\1005\050\Figures\Marcia_Figs\Figure_4-18.ai; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



Notes:
- Event 3—see Table 4-1 (original location) and Figure 4-7 (green circle).
- OBS first motions used in focal mechanism are circled in blue.

Focal Mechanisms for the M 1.24 Earthquake on 11 Feb 2014—Original NCSN Catalog Data with All OBS Data (USGS Velocity Model)

POINT BUCHON OBS PROJECT

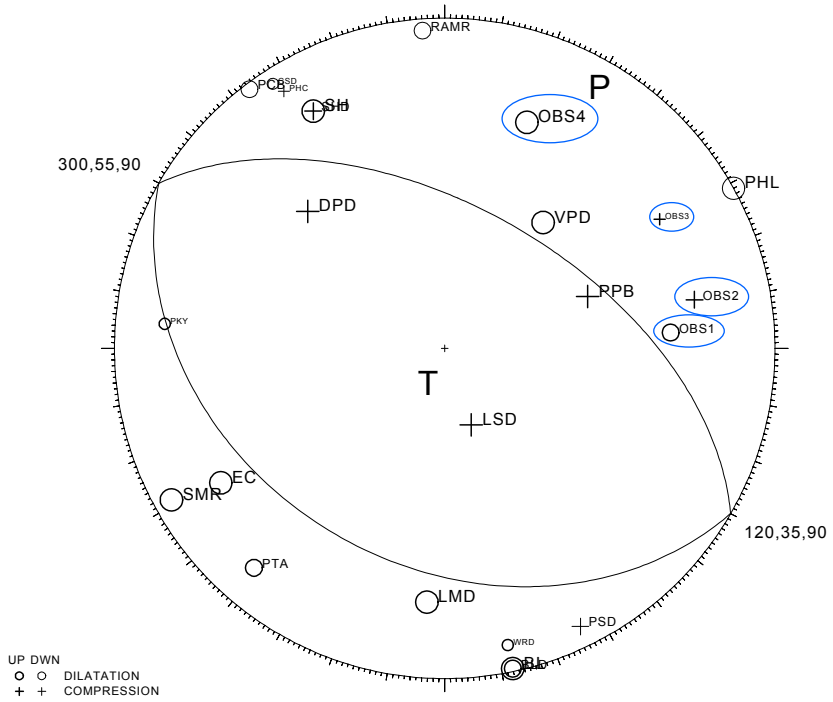
Pacific Gas and Electric Company | Figure **4-19**

20140211 13:51 36.92
35 16.63 120 50.06
DEPTH = 7.97 KM
MAG = 1.24 D

RMS = 0.13 S
DMIN = 2 KM
AZM GAP = 57
FM = 24

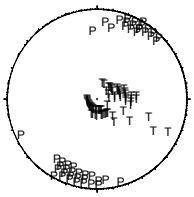
ERH = 0.3 KM
ERZ = 0.8 KM
MISFIT = 0.14 (+.05)
STDR = 0.60

STRIKE UNCERTAINTY = 8
DIP UNCERTAINTY = 10
RAKE UNCERTAINTY = 25
% MACHINE PICKS = 100



DISCREPANT OBSERVATIONS

STAT	DIST	AZM	AIN	PRMK
OBS3	11	239	115	EPU2
OBS2	12	259	114	IPU1
SHD	14	151	109	IPU1
PSD	46	154	83	IPU1
PHC	54	328	81	EPU2



Fri Mar 14 11:23:00 2014

usgs.arc

Notes:
- Event 3—see Table 4-1 (test 1) and Figure 4-7 (red circle).
- OBS first motions used in focal mechanism are circled in blue.
- Focal mechanism solution statistically fits the input first motion data.

Focal Mechanism for the M 1.24 Earthquake on 11 Feb 2014—Original NCSN Catalog Data with All OBS Data (PG&E Velocity Model)

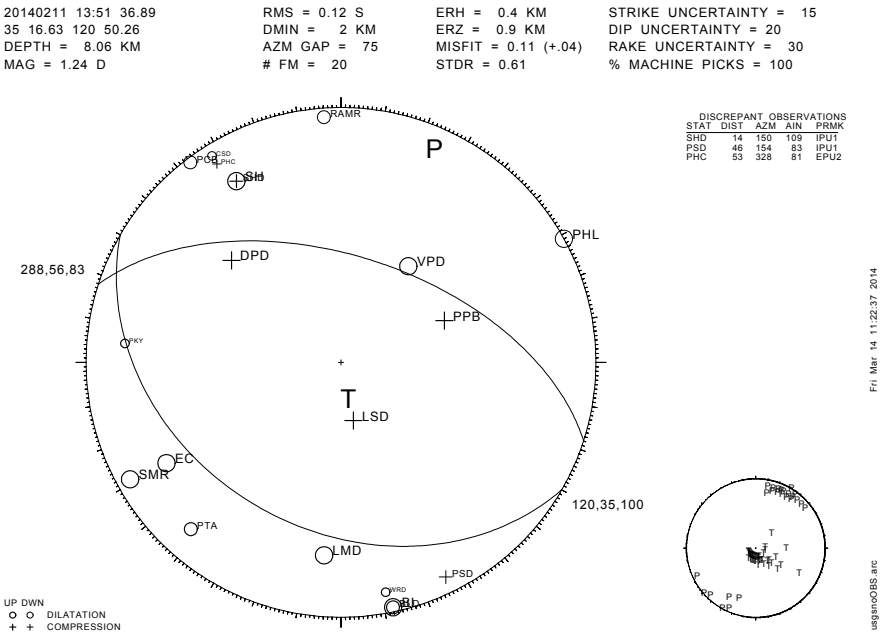
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

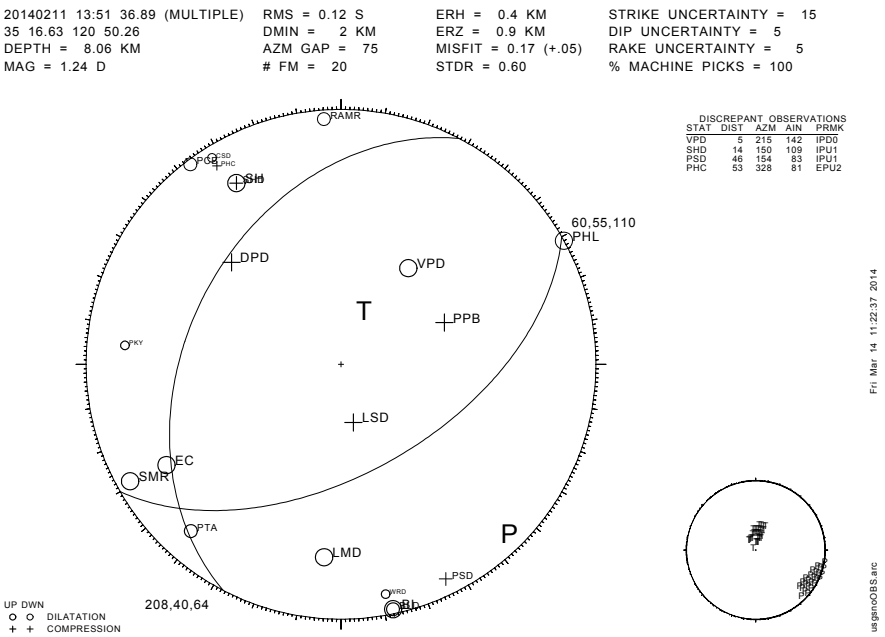
Figure **4-20**

File path: S:\1005\050\Figures\Marcia_Figs\Figure_4-20.ai; Date: 05/29/2014; User: Alex Remar, LCI; Rev.1

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



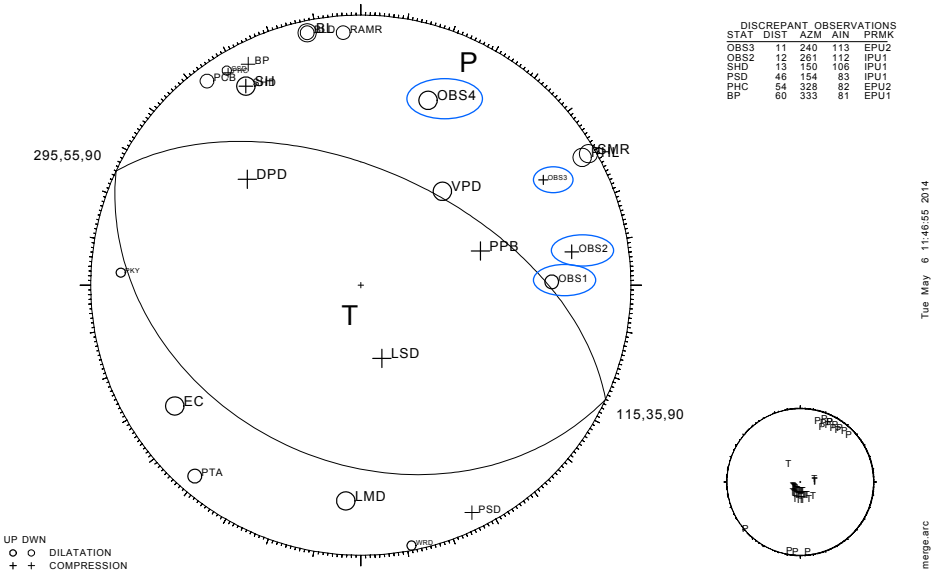
Note: Event 3—see Table 4-1 (test 2) and Figure 4-7 (yellow circle).

Focal Mechanisms for the M 1.24 Earthquake on 11 Feb 2014—Original NCSN Catalog Data with No OBS Data (PG&E Velocity Model)

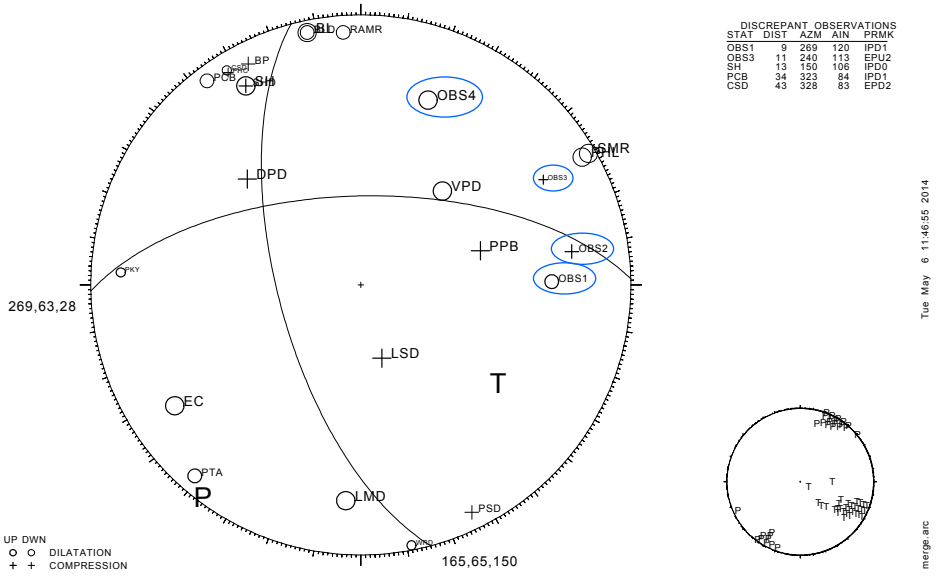
POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-21**

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data

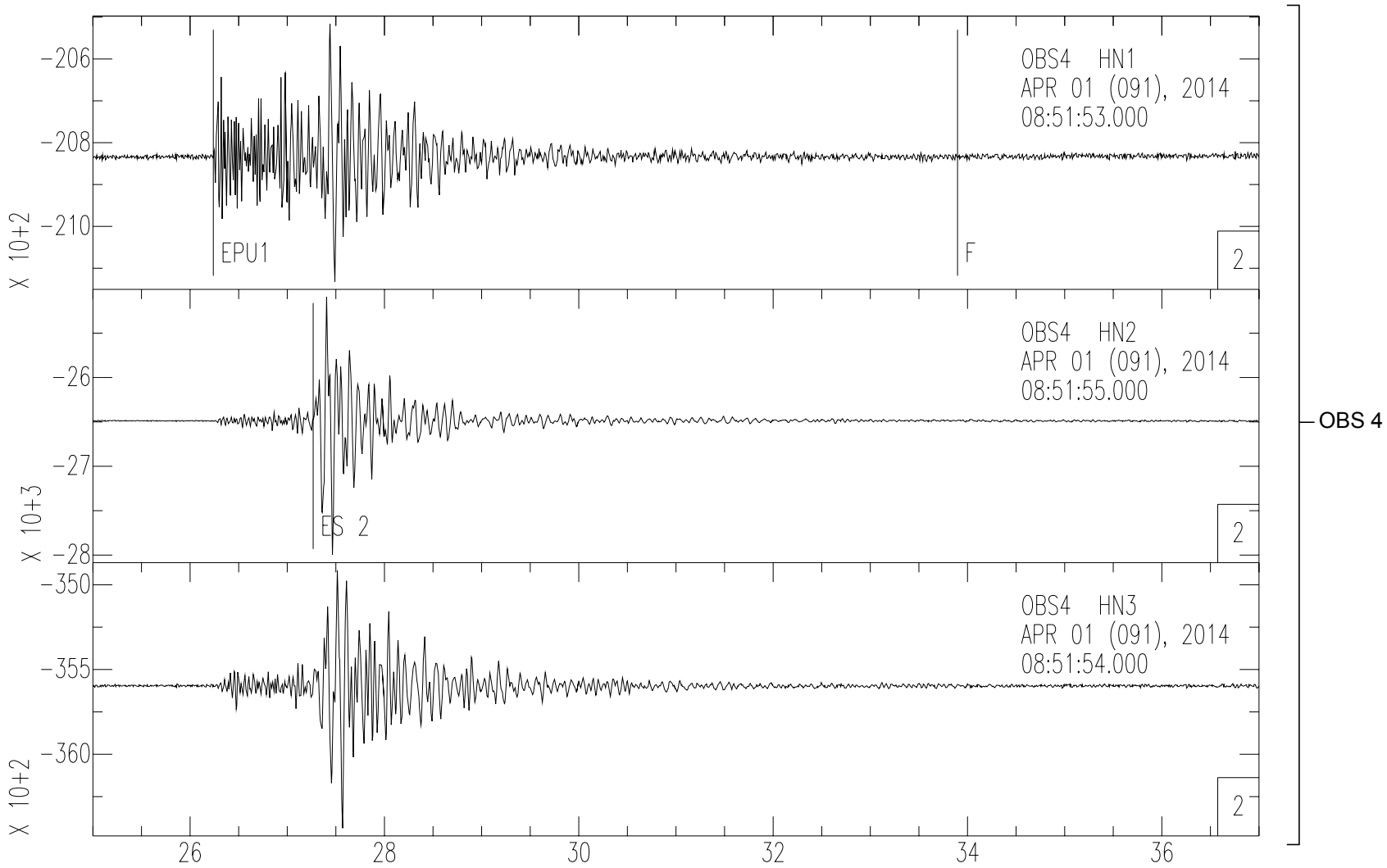


Notes:
- Event 3—see Table 4-1 (test 3) and Figure 4-7 (purple circle).
- OBS first motions used in focal mechanism are circled in blue.

Focal Mechanisms for the M 1.24 Earthquake on 11 Feb 2014—Original NCSN Catalog Data with All OBS Data and added PG&E S-Wave Picks, (USGS Velocity Model)

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company | Figure **4-22**



Notes:
- Event 4—see Table 4-1.
- For each OBS package of three traces, the top trace is vertical and the bottom two are horizontal.
- The x-axis units are time (seconds).
- The y-axis units are volts.

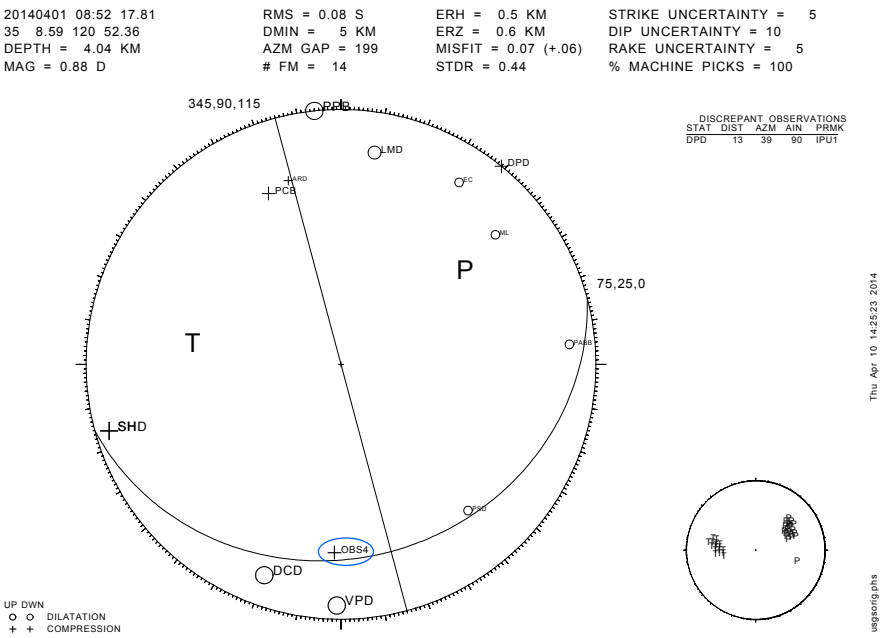
OBS-4 Recording for the M 0.88 Earthquake on 01 Apr 2014

POINT BUCHON OBS PROJECT

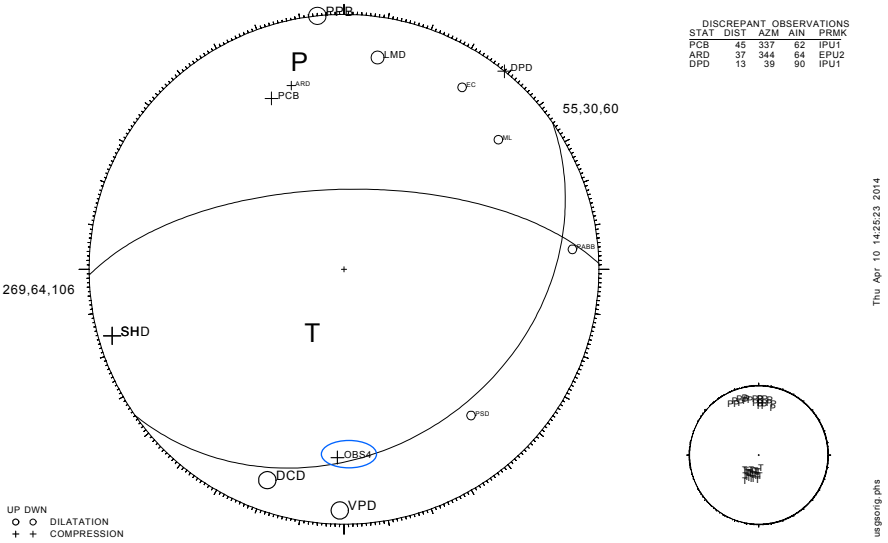
Pacific Gas and Electric Company | Figure **4-23**

Ch5.GEO.DCPP.TR.14.04 R0

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



Notes:
- Event 4—see Table 4-1 (original location) and Figure 4-7 (green circle).
- OBS first motions used in focal mechanism are circled in blue.

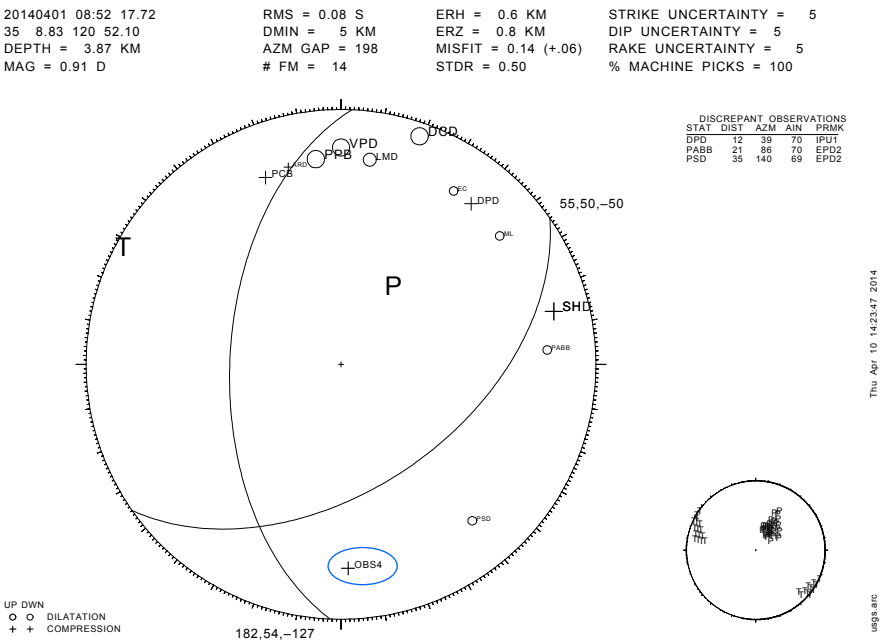
Focal Mechanisms for the M 0.88 Earthquake on 01 Apr 2014—Original NCSN Catalog Data with OBS-4 Data (USGS Velocity Model)

POINT BUCHON OBS PROJECT

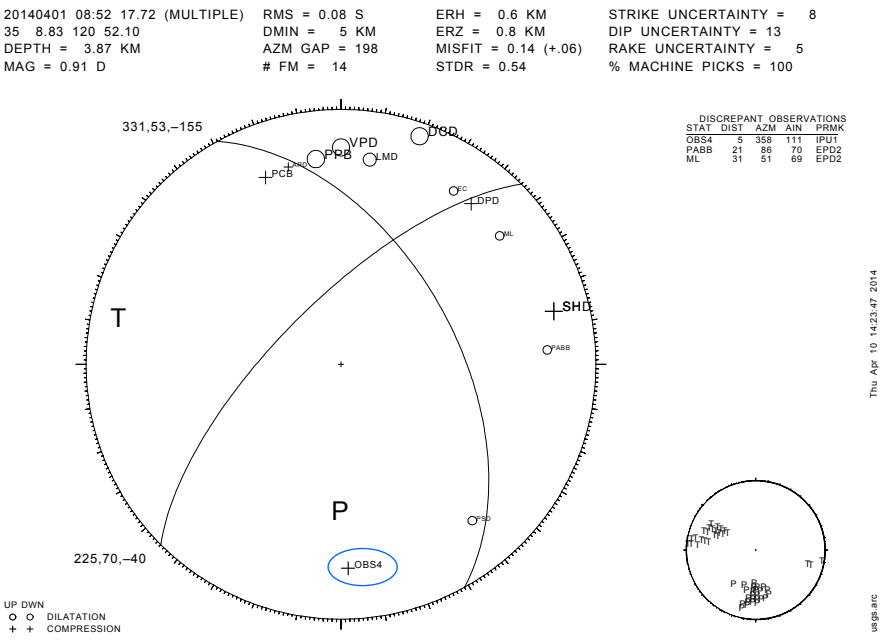
Pacific Gas and Electric Company

Figure **4-24**

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



Notes:
- Event 4—see Table 4-1 (test 1) and Figure 4-7 (red circle).
- OBS first motions used in focal mechanism are circled in blue.

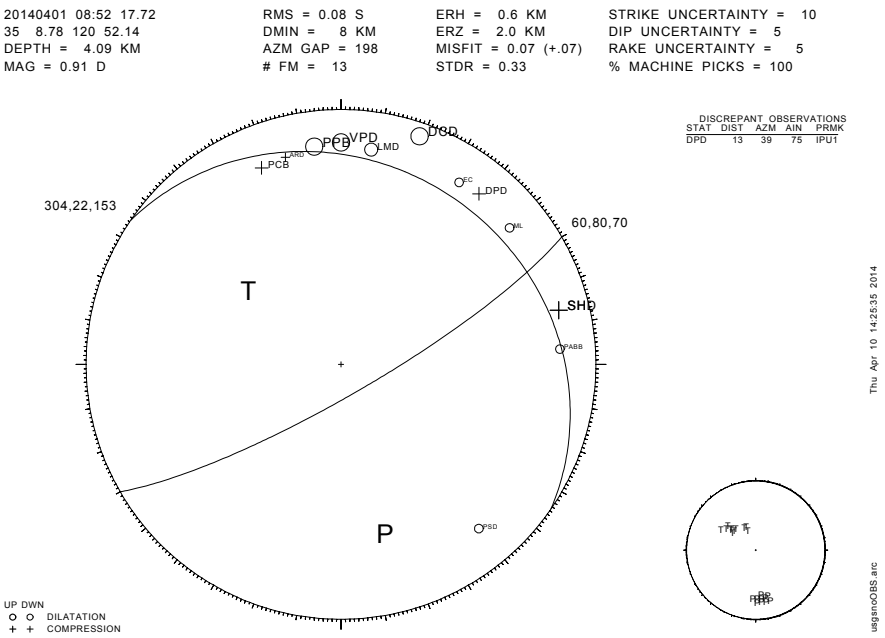
Focal Mechanisms for the M 0.88 Earthquake on 01 Apr 2014—Original NCSN Catalog Data with OBS-4 Data, (PG&E Velocity Model)

POINT BUCHON OBS PROJECT

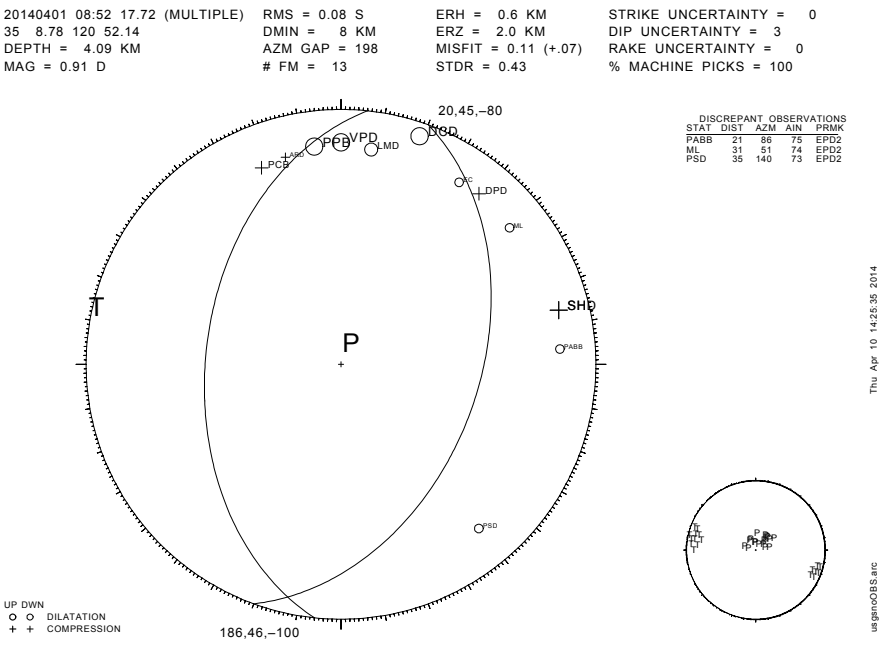
Pacific Gas and Electric Company

Figure **4-25**

(a) Focal mechanism solution that statistically fits the input first motion data



(b) Multiple focal mechanism solution that also fits the input first motion data



Note: Event 4—see Table 4-1 (test 2) and Figure 4-7 (yellow circle).

Focal Mechanisms for the M 0.88 Earthquake on 01 Apr 2014—Original NCSN Catalog Data with No OBS Data (PG&E Velocity Model)

POINT BUCHON OBS PROJECT

Pacific Gas and Electric Company

Figure **4-26**