Monitoring Active Crustal Faults in Washington: Two PASSCAL Array Experiments

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ABSTRACT

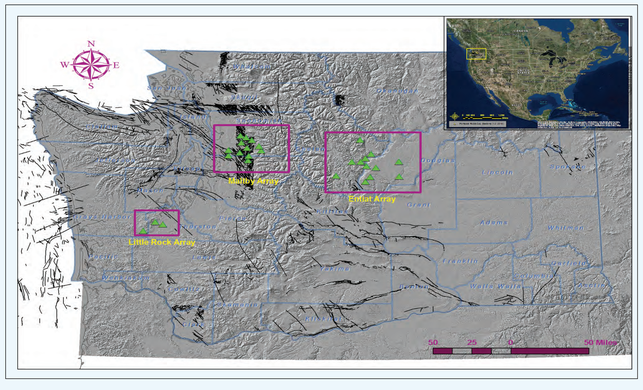
The Washington Geological Survey installed portable broadband seismographs to record earthquakes near Maltby/Granite Falls. This was done in support of our geologic mapping in areas northeast of the Seattle region and near the Entiat earthquake cluster area in central Washington. We deployed 14 IRIS-PASSCAL instruments in the mapping areas in July 2015 and 12 instruments in the Entiat area in September 2016.

We recorded a 20 km deep M3.5 mainshock event on July 1st, 2015, followed by multiple aftershocks very near our PASSCAL array in Granite Falls. The nearest and farthest stations of the portable array that recorded this cluster of earthquakes were at 1 km and 20 km distances, respectively, whereas the closest regional Pacific Northwest Seismic Network (PNSN) station was 10 km away. We analyzed first motions of these earthquakes, local magnitudes ranging from 3.5 to 2.0, to determine fault mechanisms compared to the PNSN solutions. Results show that some of the fault plane solutions of the M<3 events were significantly improved with the new portable station coverage.

We installed 12 PASSCAL rapid deployment instruments for monitoring the Entiat earthquake cluster area, Chelan County, which is the most seismically active region in Washington. The array recorded a 2.1 km deep M3.3 mainshock event on July 24th, 2017, followed by a few aftershocks.

The new PASSCAL instrument deployments help significantly improve focal mechanism solutions of the local (M<=3) and regional (M>3) events. PNSN focal mechanism solutions are verified and recalculated based on our new additional stations; new focal mechanism solutions are determined. Our additional deployments of stations in the Entiat area made it possible to determine new focal mechanisms for small events. These observations combined with regional network recordings can now be used for relocation of events (specifically in earthquake clustered areas), crustal velocity estimation, and additional focal mechanism studies. We will present local crustal earthquakes recorded by the regional and new portable arrays, and suggest correlations to faults recently identified by geologic mapping and geophysical studies.

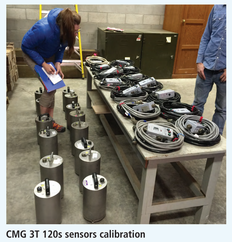
Locations of PASSCAL (Portable) Arrays in Washington State, USA



Deployments of IRIS-PASSCAL Instruments


RefTek RT130 dataloggers

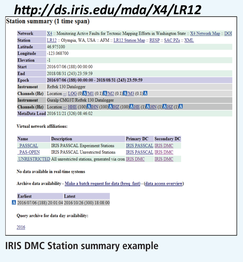

CMG 3T 120s sensors


CMG 3T 120s sensors calibration


CMG 3T 120s installation

Guralp CMG-3T Broadband (120s -50Hz flat velocity response, with remote electronic mass locking, unlocking, and centering)

http://ds.iris.edu/mda/X4/LR12


IRIS DMC Station summary example

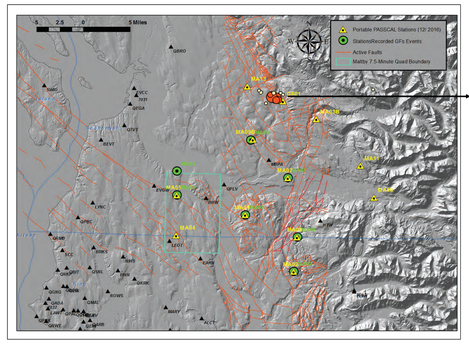

An installed Guralp CMG-3T broadband station

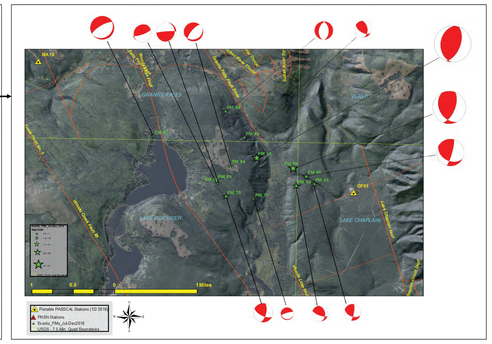
http://www.fdsn.org/networks/detail/X4_2016/


L-22 3-component short-period Sensor (2 Hz, 0.70 damping, 88 V/m/s sensitivity)

ACTIVE FAULT MONITORING AND SEISMOLOGICAL STUDIES TO AID 7.5-MINUTE QUADRANGLE MAPPING EFFORTS IN WASHINGTON STATE

Maltby 7.5-Minute Quadrangle Array



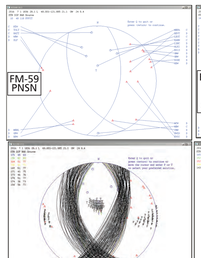


PNSN

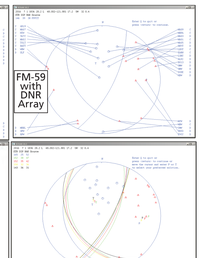
FMID	Mag	Evid	Time UTC	Depth Km	str1	dip1	rake1	str2	dip2	rake2	Type
FM_59	3.4	611761 66	7/1/2016 18:36	20.1	10	45	100	176	46	80	OBLIQUE REVERSE
FM_60	1.9	611762 06	7/1/2016 20:05	15.6	70	75	100	216	18	57	OBLIQUE REVERSE
FM_61	1	611762 16	7/1/2016 20:18	18.4	30	60	130	151	48	42	REVERSE
FM_62	2.2	611762 36	7/1/2016 20:32	18.4	105	70	60	344	36	144	OBLIQUE REVERSE
FM_63	2.6	611762 81	7/1/2016 21:18	17.6	285	75	-50	32	42	-157	REV-OBL STRK-SLP
FM_64	1.6	611763 41	7/2/2016 0:13	13.7	325	90	-110	235	20	0	OBLQ NORM
FM_65	1.6	611765 06	7/2/2016 8:42	15.4	95	25	-100	286	65	-85	REV-OBL STRK-SLP
FM_66	2.2	611768 86	7/3/2016 13:47	18	280	75	-60	34	33	-152	REV-OBL STRK-SLP
FM_67	1.7	611626 27	7/6/2016 9:01	13.4	40	45	-110	247	48	-71	NORMAL
FM_68	1.8	611720 17	7/26/2016 19:53	14.9	190	45	-180	356	46	-100	NORMAL
FM_69	1.8	611929 36	8/11/2016 18:10	14.85	70	75	100	216	18	57	OBLIQUE REVERSE
FM_70	2.2	611846 32	8/25/2016 12:17	15.76	80	90	90	305	0	135	REV-OBL STRK-SLP
FM_71	1.9	612021 86	8/31/2016 6:26	18.19	105	15	-60	254	77	-98	OBLQ NORM

DNR

str1	dip1	rake1	str2	dip2	rake2
153	39	49	21	62	118
121	55	54	353	49	130
185	35	78	20	56	98
110	70	58	351	37	146
112	48	18	10	77	137
219	72	-101	71	21	-60
13	18	18	266	85	107
118	38	16	15	80	127
117	63	28	13	65	150
103	14	-61	253	78	-97



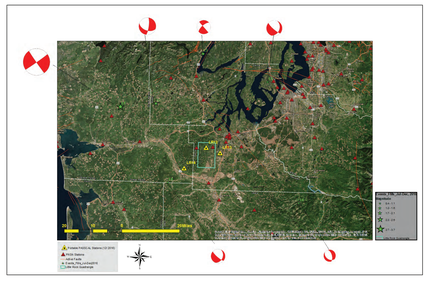
July 1 3.4M PNSN Picks
5 deg error (91 solutions)



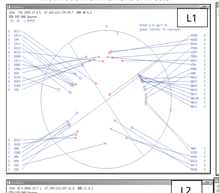
July 1 3.4M PNSN/DNR
5 deg error (5 solutions)

Focal mechanism solutions are determined using SEISAN [http://seisan.info/] (first motion FPFIT HASH, FOCMEC can be used simultaneously)

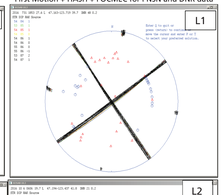
Littlerock 7.5 Minute Quadrangle Array

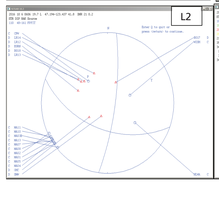


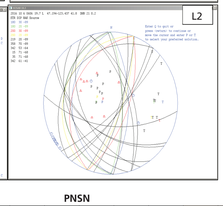
First Motion for PNSN and DNR data



First Motion + HASH + FOCMEC for PNSN and DNR data







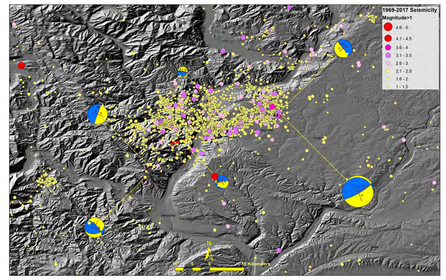
PNSN

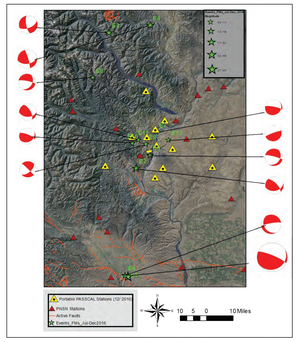
FMID	Mag	Evid	Depth Km	PNSN_ Type	str1	dip1	rake1	str2	dip2	rake2
L1	3.7	61173722	35.2	REV-OBL STRK-SLP	220	85	20	128	70	175
L2	2.6	61202567	41.1							
L3	2.4	61172832	45.4	STRIKESLIP	243	70	175	335	85	20
L4	1.6	61206836	9.4	OBLIQUE REVERSE	60	5	50	280	86	93
L5	1.5	61213556	53							
L6	1.5	61202201	43.2							

DNR

	str1	dip1	rake1	str2	dip2	rake2
STRIKESLIP	55	88	-2	145	88	-178
NORM-OBLQ STRKSLP	110	48	-162	8	77	-43
REV-OBL STRK-SLP	319	90	22	229	68	180
OBLQ NORM	126	38	-122	344	59	-68
OBLQ NORM	131	78	-122	23	34	-22
OBLQ NORM	118	88	-47	210	43	-177

EARTHQUAKE CLUSTER MONITORING IN ENTIAT, CHELAN, WASHINGTON

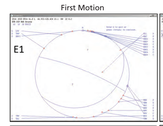




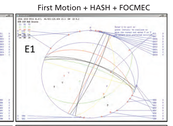
DNR

FMID	Mag	Evid	Depth Km	str1	dip1	rake1	str2	dip2	rake2	Type
E1	3.1	61204087	7.8	60	18	38	293	79	104	REV-OBL STRK-SLP
E2	2.1	61204017	5.4	78	38	38	316	68	122	REV-OBL STRK-SLP
E3	1.9	61210856	5.9	67	58	-22	169	72	-146	NORM-OBLQ STRKSLP
E4	1.7	61227436	1.4	81	48	10	344	83	138	STRIKESLIP
E5	1.4	61220402	5.4	31	30	-162	285	81	-61	NORM-OBLQ STRKSLP
E6	1.4	61204202	6.6	150	28	-22	260	80	-116	NORM-OBLQ STRKSLP
E7	1.1	61220272	2.5	48	18	38	281	79	104	REV-OBL STRK-SLP
E8	1	61219622	8.5	28	37	-160	282	778	-55	NORM-OBLQ STRKSLP
E9	0.8	61201897	1.9	48	58	-175	315	86	-32	STRIKESLIP
E10	0.7	61223516	2.2	58	28	38	293	73	113	REV-OBL STRK-SLP
E11	0.7	61210821	7	90	45	38	331	64	128	REV-OBL STRK-SLP
E12	0.4	61204242	4.5	57	7	78	249	83	92	REVERSE

First Motion

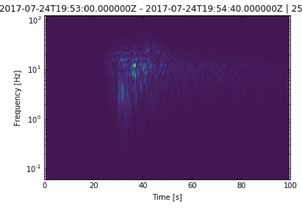


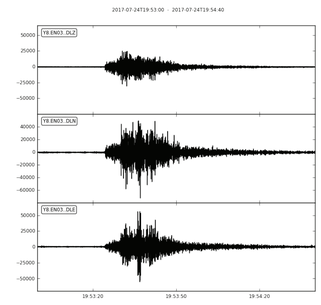
First Motion + HASH + FOCMEC

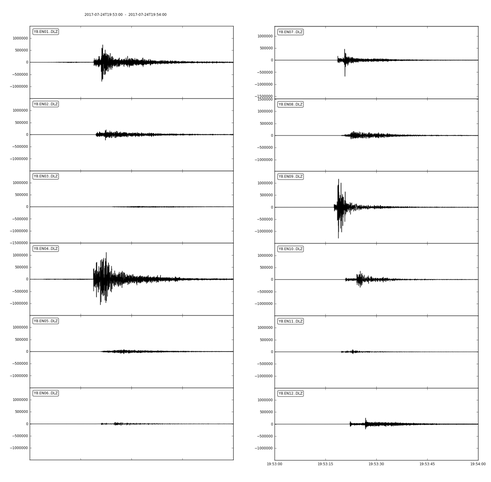


The Entiat network recorded an M3.3 earthquake on July 24, 2017

Y8.EN03..DLE | 2017-07-24T19:53:00.000000Z - 2017-07-24T19:54:40.000000Z | 250.0 Hz, 25001 samples







CONCLUSIONS

- The new PASSCAL instrument deployments help significantly improve focal mechanism solutions of the local (M<=3) and regional (M>3) events.
- Regional Network (PNSN) focal mechanism solutions are verified and recalculated based on our new additional stations; improved or new focal mechanism solutions are determined using new array information.
- Additional deployments of stations in the Entiat area enable the determination of new focal mechanisms for small events.
- Our data is available, and we update the data every 1 to 2 months.
- We plan to operate our PASSCAL portable arrays over the next 1 to 2 years, and we will be working on additional event relocations, crustal velocity estimations, and focal mechanism studies.

REFERENCES

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Washington State Geology Portal: [http://www.dnr.wa.gov/geologyportal]

IRIS/PASSCAL [https://www.passcal.nmt.edu/]

IRIS DMC [http://ds.iris.edu/ds/nodes/dmc/]

PNSN [https://www.pnsn.org/]

SEISAN [http://seisan.info/]

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ACKNOWLEDGMENTS

This project is funded by FEMA-CTP program (FY16) to support RiskMAP project effofts in Chelan and Okanogan counties, WA, and by USGS-STATEMAP program (FY2016) to support 1:24,00-scale geologic mapping in Washington State. We thankTom Brocher (USGS) who initially brought the Entiat earthquake cluster problem to our attention and his guidance during the instrument deployments, and to the Pacific Northwest Seismic Network (PNSN) for the data/information support. Finally, we thank IRIS-PASSCAL staff for their tremendous support and efforts to make our deployment of the instruments and data services go smoothly.