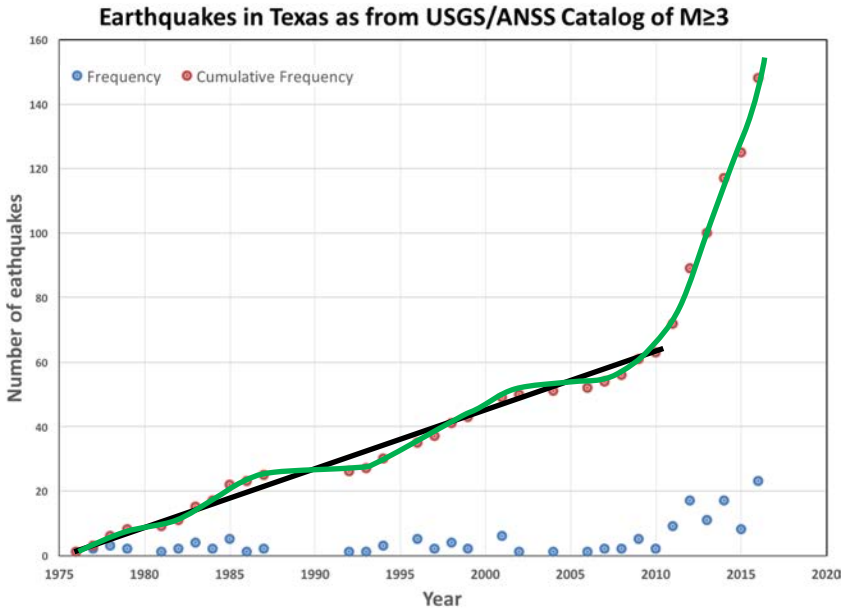
Texas Seismic Network (TexNet)

A. Savvaidis

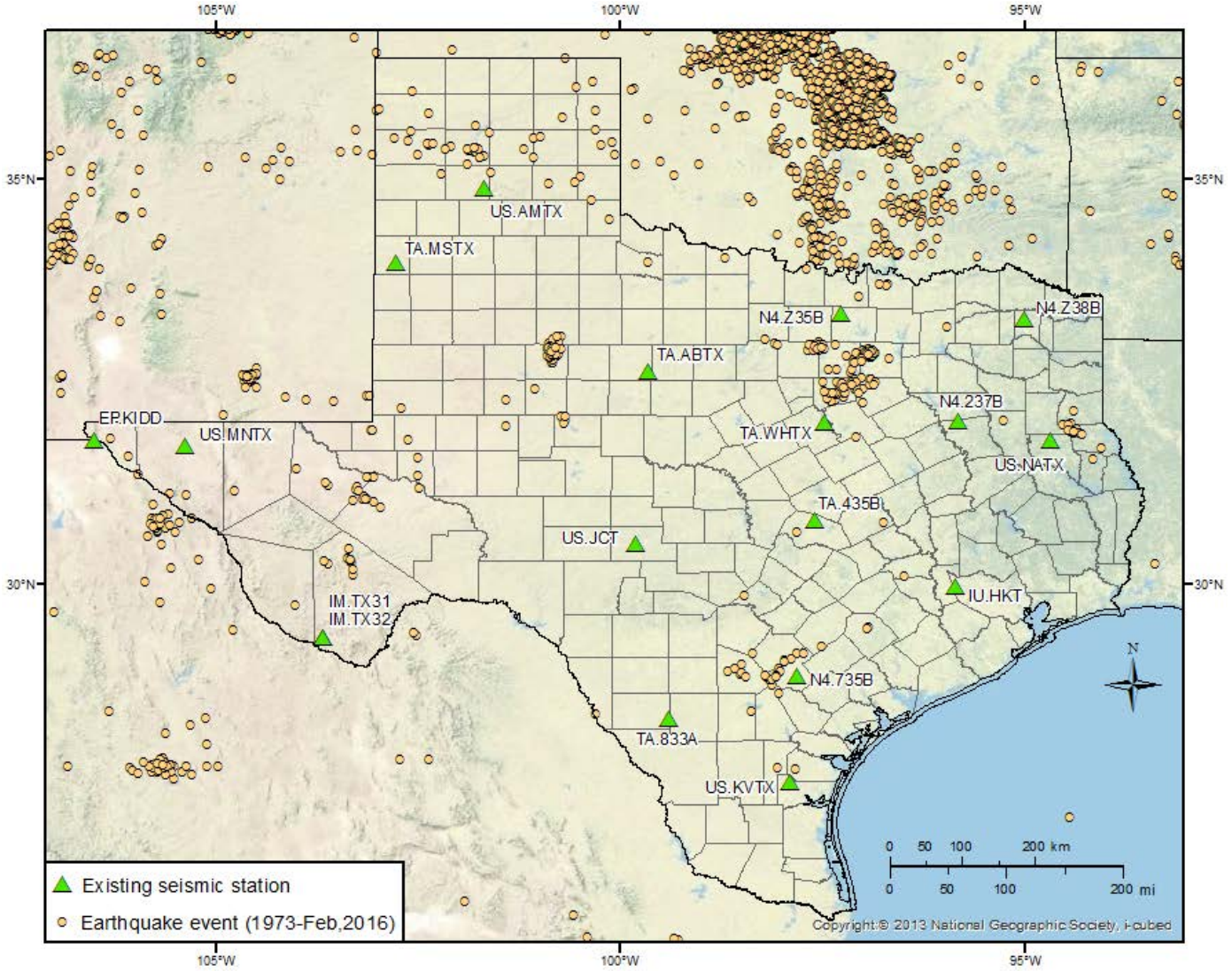
PI Seismology and Manager of the Texas Seismological Network

Bureau of Economic Geology

Seismic Activity in Texas



Savvaidis, BEG



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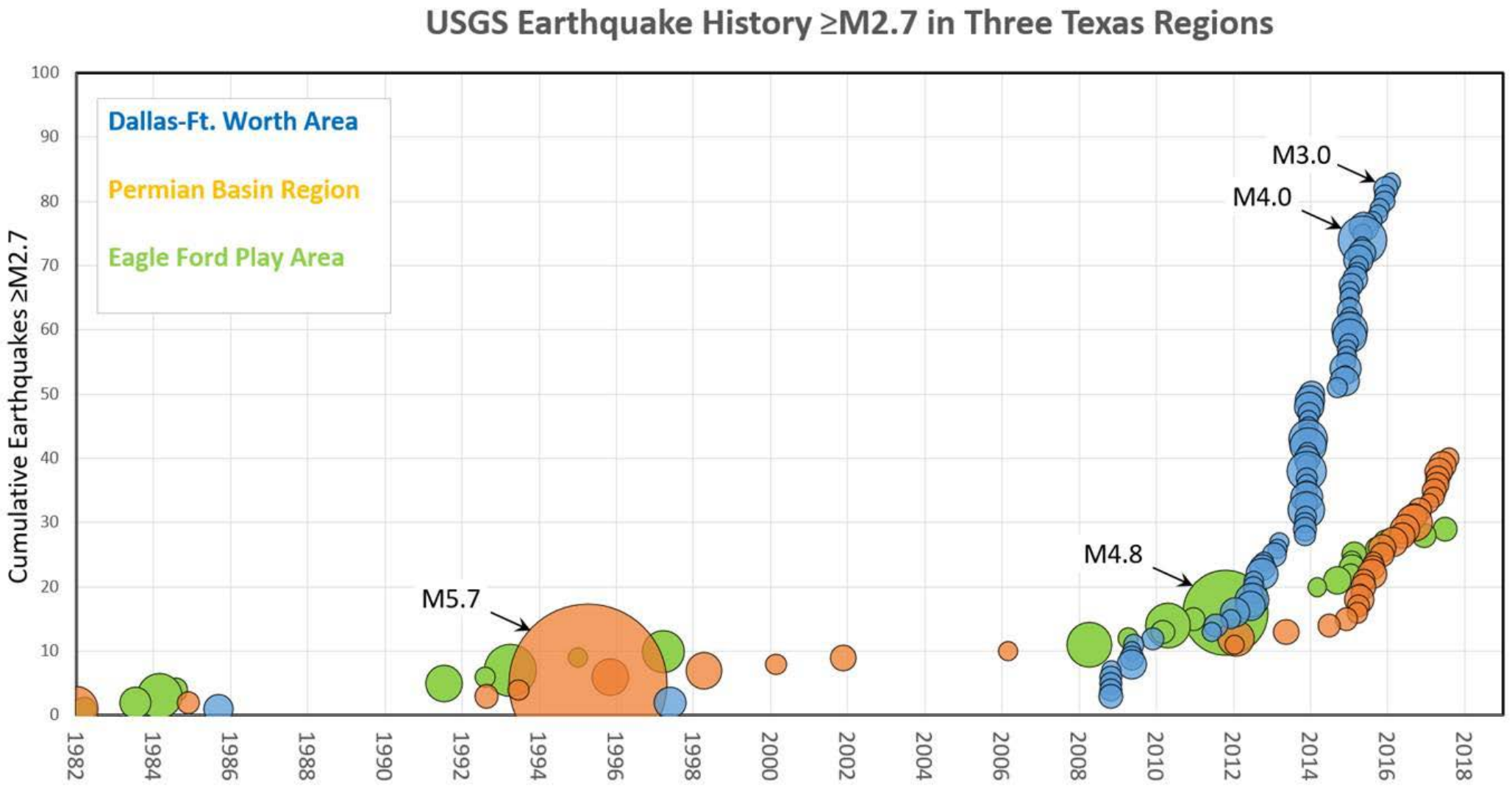
Cumulative Seismicity in Texas



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Texas' Response to Public Concerns about Increasing Rates of Seismicity

March 2014 – Railroad Commission of Texas (RRC) hires a seismologist to provide technical support on earthquake issues

November 2014 – RRC issues new regulations designed to address disposal well operations in areas of historical or future seismic activity. Components include†:

- Applicants are required to search USGS seismic database for historical earthquakes within a circular area of 100 square miles around a proposed, new disposal well (~5.6 mile radius);
- Clarifying RRC's authority to modify, suspend or terminate a disposal well permit, or modify operations, if scientific data indicates a disposal well could be contributing to seismic activity;
- Increased disclosure of reported volumes and pressures, at RRC's discretion
- RRC may require applicant to provide additional technical information to demonstrate disposal fluid confinement.

†paraphrased from http://www.rrc.state.tx.us/all-news/102814b/

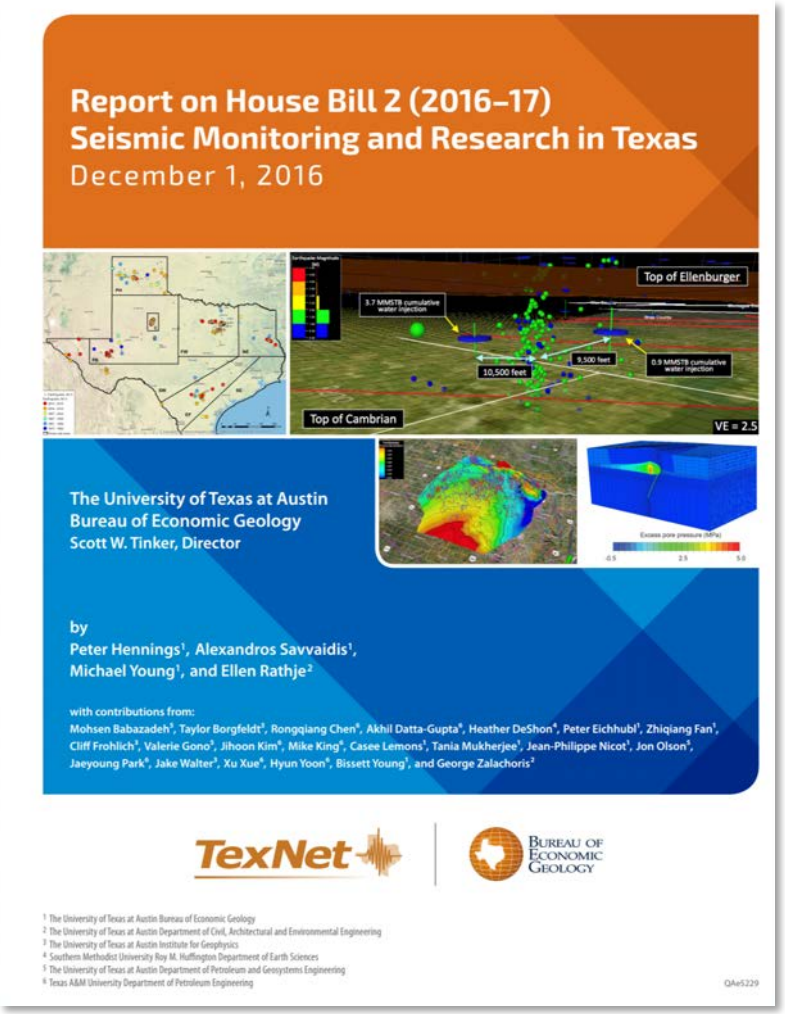
Texas' Response to Public Concerns about Increasing Rates of Seismicity

Bill Text: TX HB2 | 2015-2016 | 84th Legislature

Texas House Bill 2 (*In Recess*)

TX State Legislature page for HB2

SECTION 16. THE UNIVERSITY OF TEXAS AT AUSTIN: BUREAU FOR ECONOMIC GEOLOGY. (a) In addition to amounts previously appropriated for the state fiscal biennium ending August 31, 2015, $4,471,800 is appropriated out of the general revenue fund to The University of Texas at Austin for the two-year period beginning on the effective date of this Act for the purchase and deployment of seismic equipment, maintenance of seismic networks, modeling of reservoir behavior for systems of wells in the vicinity of faults, and establishment of a technical advisory committee.



http://www.beg.utexas.edu/files/content/texnet/docs/TexNet-Report-2016.pdf

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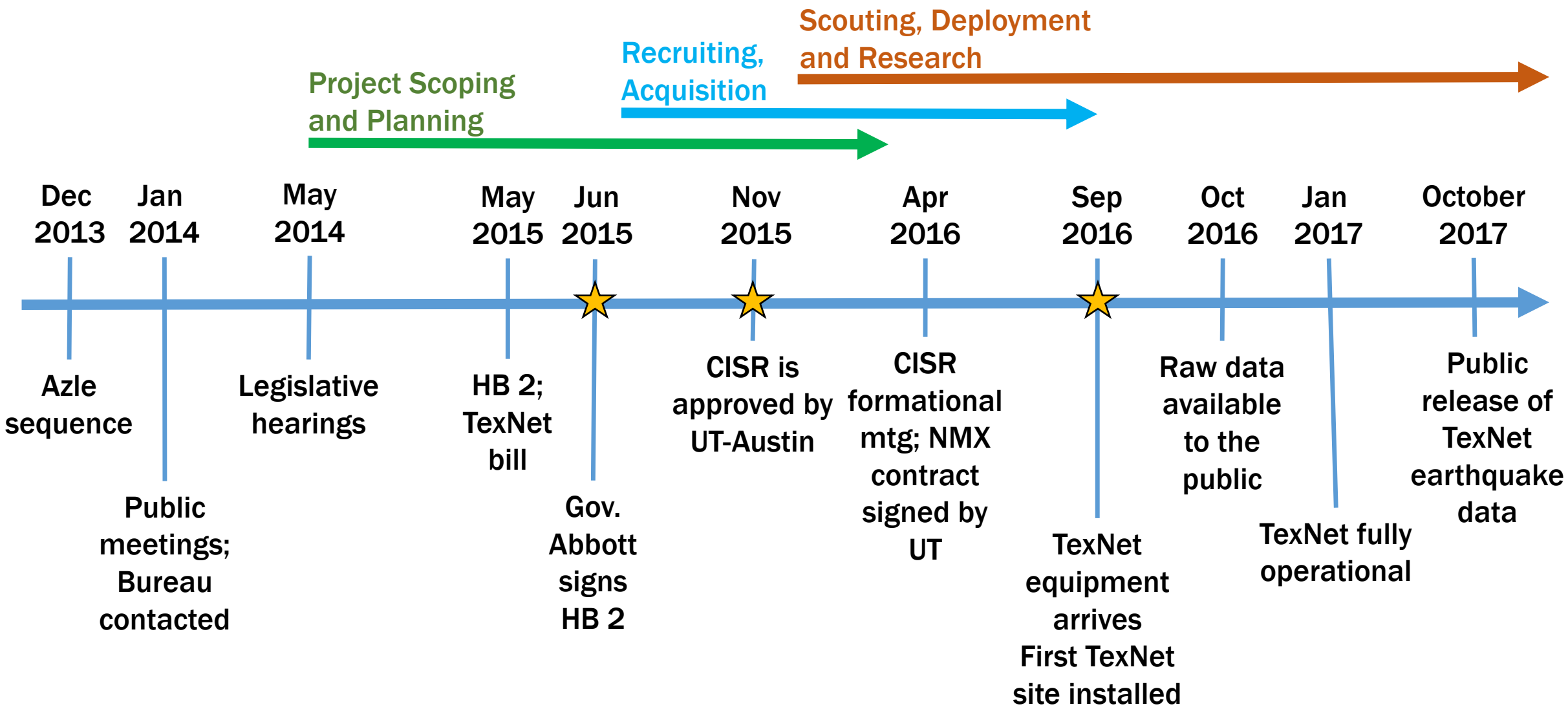
Timeline of Significant Events and Bureau Involvement



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Timeline not to scale; dates reasonably close

TexNet-CISR Organization

Governor – Legislature

Technical Advisory Committee

Robie Vaughn (Chair)	Dana Jurick	Dan Hill
Chris Hillman	Hal Macartney	Brian Stump
Aaron Velasco	Kris Nygaard	Scott Tinker

Bureau Directorate

Scott Tinker, Michael Young

TexNet-CISR Program Leadership

Peter Hennings, PI Subsurface Integration and Industry Liaison
Ellen Rathje, PI Earthquake Hazard and Risk
Alexandros Savvaidis, PI Seismology and TexNet Manager

CISR Science Advisory Committee

SAC Representative	Organization
Peter Hennings	UT-BEG
Ellen Rathje	UT-CAEE
Alexandros Savvaidis	UT-BEG
Cody Comiskey	Anadarko
Cal Cooper	Apache
Rongmao Zhou	BHP
Jeff Nunn	Chevron
Doug Klepacki	Cimarex
Seth Busetti	ConocoPhillips
Rod Gertson	Devon
Beatriz Garcia-Fresca	Equinor
Robert Kidney	EOG
Tim Tyrell	ExxonMobil/XTO
Cory Christie	QEP Resources
Pete Christianson	Marathon
Klaas Koster	Occidental
Kevin Woller	Pioneer
Ulrich Zimmer	Shell
Tony Lupo	SM-Energy

TexNet Network

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Bissett Young[B]
Caroline Breton[B]
Poe Chen[B]
Stefanie Whittaker[B]
Clay Templeton[B]
Patricia Martone[B]
John Andrews[B]
Field Engineer [B]
Earthquake Analyst [B]

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Dino Huang[B]
Dmitrii Merzlikin[B]
Ibinabo Bestmann[B]
Cliff Frohlich[I]
Ellen Rathje[C]
Heather DeShon[S]
Louis Quinones[S,2]
Paul Ogwari[S,1]
Oner Sufri[S,1]
Chris Hayward[S]
Aibing Li[H]
Hejun Zhu[D]
Marianne Karplus[E]
Stephen Veitch[E]
Diane Doser[E]
Jenna Faith[E,2]

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Casee Lemons[B]
Katie Smye[B]
Robin Dommisse[B]
Reinaldo Sabbagh[B]
Lily Horne[B]
Chris Zahm[B]
JP Nicot[B]
Rebecca Gao[B]
Hydrogeologist RA TBD[B]
Guin McDaid[B]

SwRI Southwest Research Institute
Ronald McGinnis, Alan Morris

Golder Associates
Paul LaPointe et al.

Stanford School of Earth, Energy & Environmental Sciences
Stanford Center for Induced and Triggered Seismicity
Jens Lund-Snee, Mark Zoback

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Mohsen Babazadeh[P,2]
Peter Eichhubl[B]
Mahdi Haddad[B,1]
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Zhiqiang Fan[B,1]
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Michael King[T]
Jihoon Kim[T]
Rongqiang Chen[T,2]
Xu Xue[T,2]
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Hyun Yoon[T]

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Brady Cox[C]
Michael Yust[C,2]
Patricia Clayton[C]
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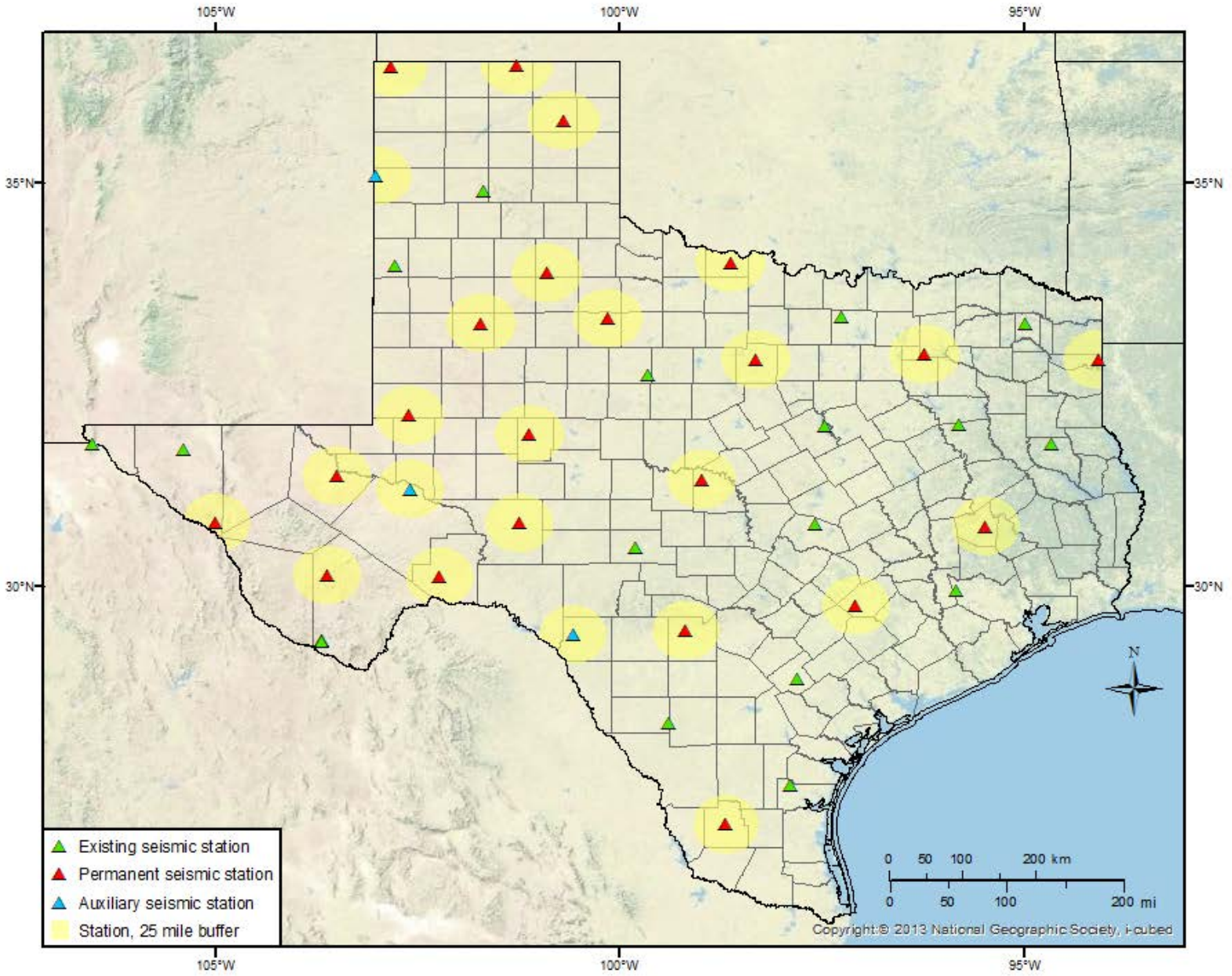
Scott Staniewicz[A,2]
Qian Yang[B]
John Hupp[B]

[B] Bureau of Economic Geology
[I] UT Institute for Geophysics
[P] UT Petroleum Geosystems and Eng
[C] UT Civil, Arch, and Envir Engineering
[A] UT Aerospace Engineering
[T] Texas A&M Petroleum Engineering
[S] SMU Geosciences
[H] University of Houston Seismology
[D] University of Texas at Dallas Seismology
[E] University of Texas at El Paso Seismology
[1]Post Doc [2]PhD student [3]MS student
gray = transitioning out of TexNet-CISR
underlined = ~full-time TexNet-CISR

Program Coordinator Margo Grace[B]
Communications and Land Management Mark Blount [B]

Texas Seismological Network Plan (SSA meeting Reno, April 2016)

- Fill in the gaps
- Add 22 additional stations, providing a backbone of 40 station
- Consider auxiliary sites



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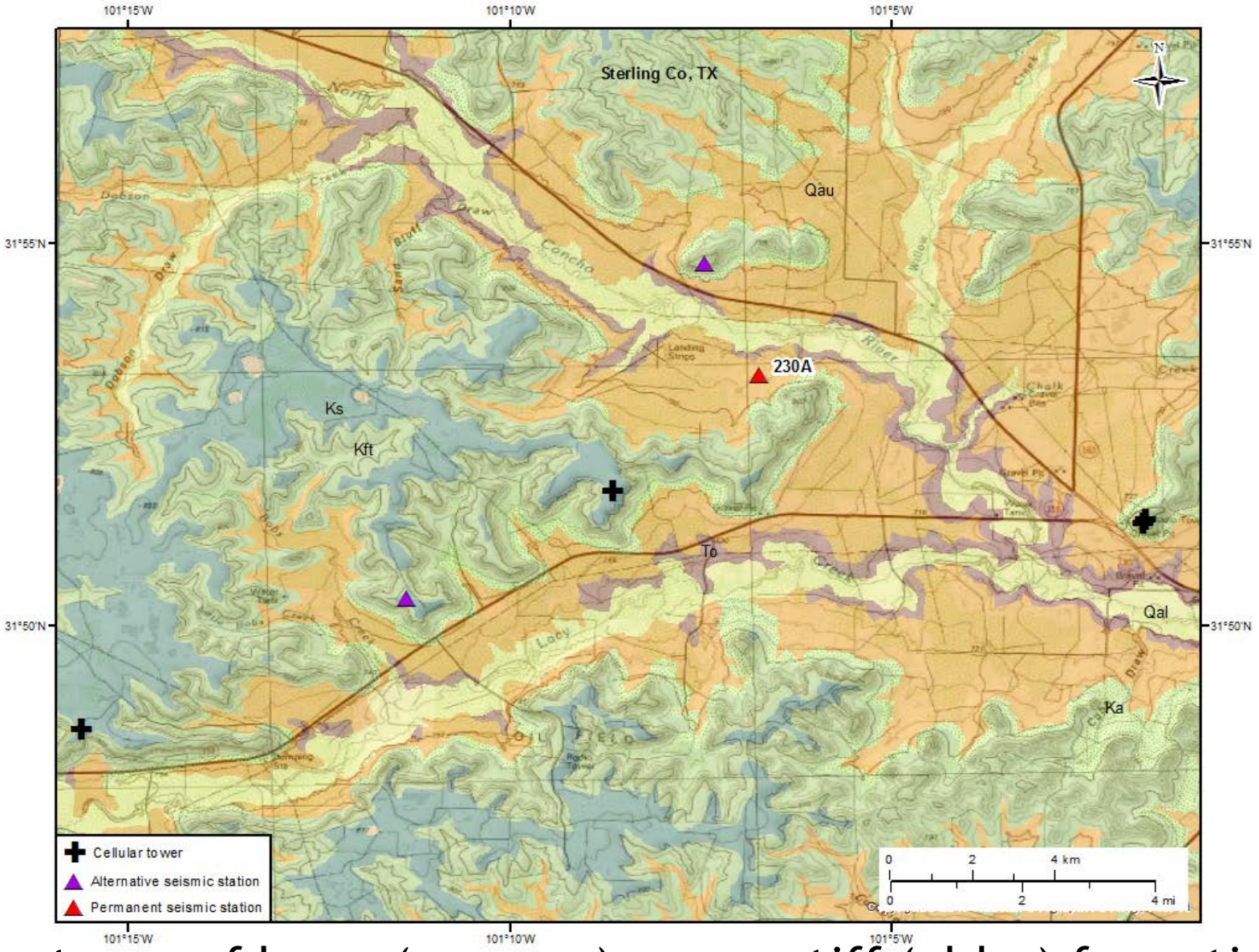
Factors to Assess Possible Station Locations

- Seismicity
- Existing broadband real-time stations
- Existing information from TA Seismological Stations
  - Noise level (Power Density Function)
  - Soil amplification (Noise and Earthquake Data)
  - Shear wave velocity (Vsz)
- Site Geology - Topography
- Tectonics
- Location of oil & gas wells
- Cell coverage

Example of Factor: Site Geology &Topography

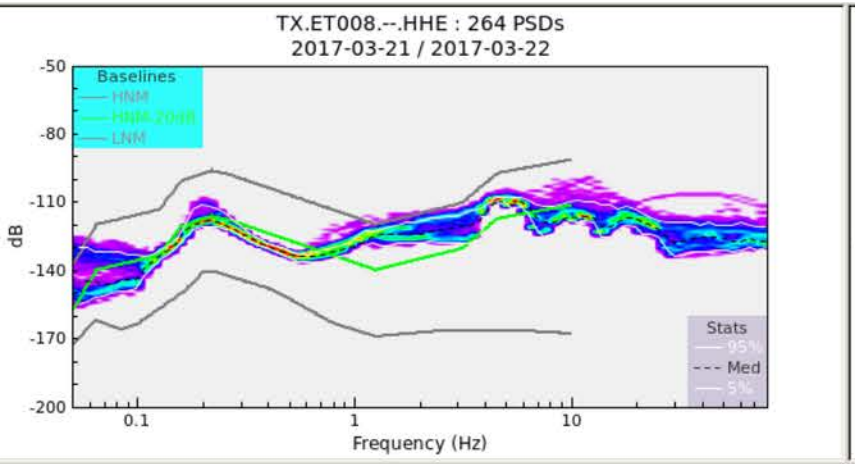
Higher elevation areas are prioritized

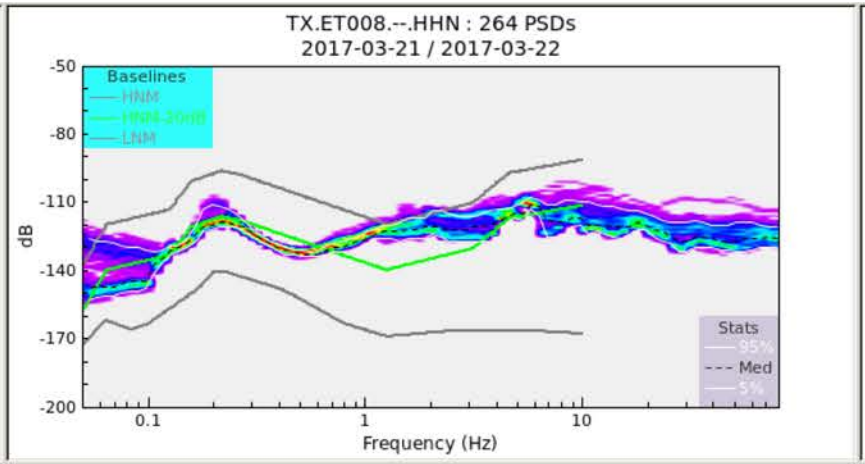
- Stiff material
- Isolated
- Cell coverage

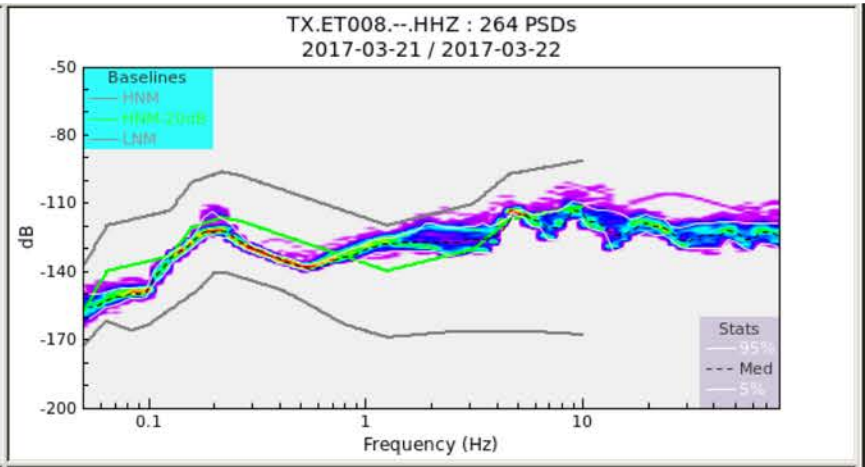


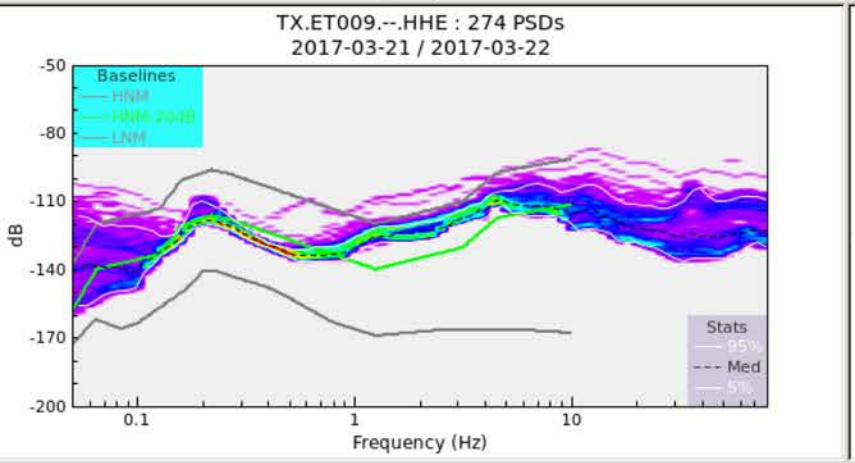
Importance of loose (younger) versus stiff (older) formations

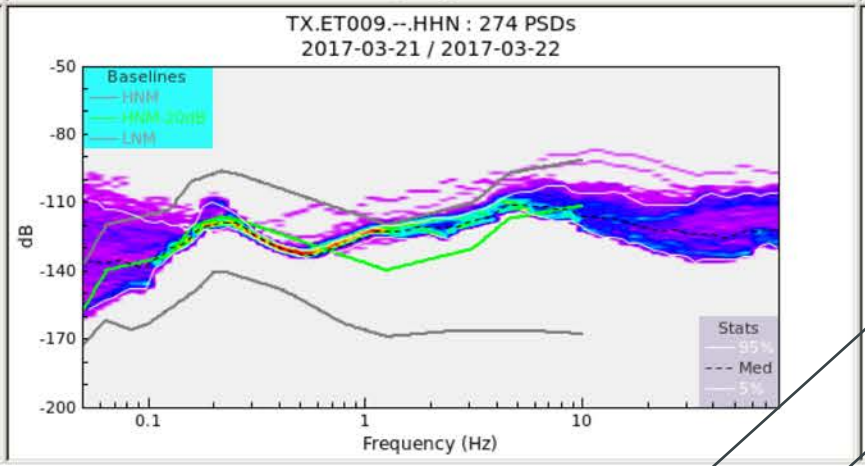
TexNet 24h Noise Tests and High Noise Limits

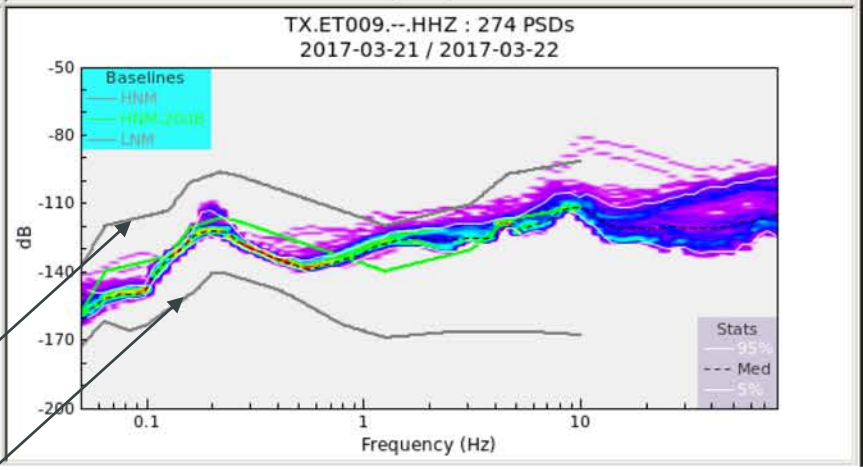












New High Noise Model

New Low Noise Model

Peterson 1993; USGS OFR 93-322

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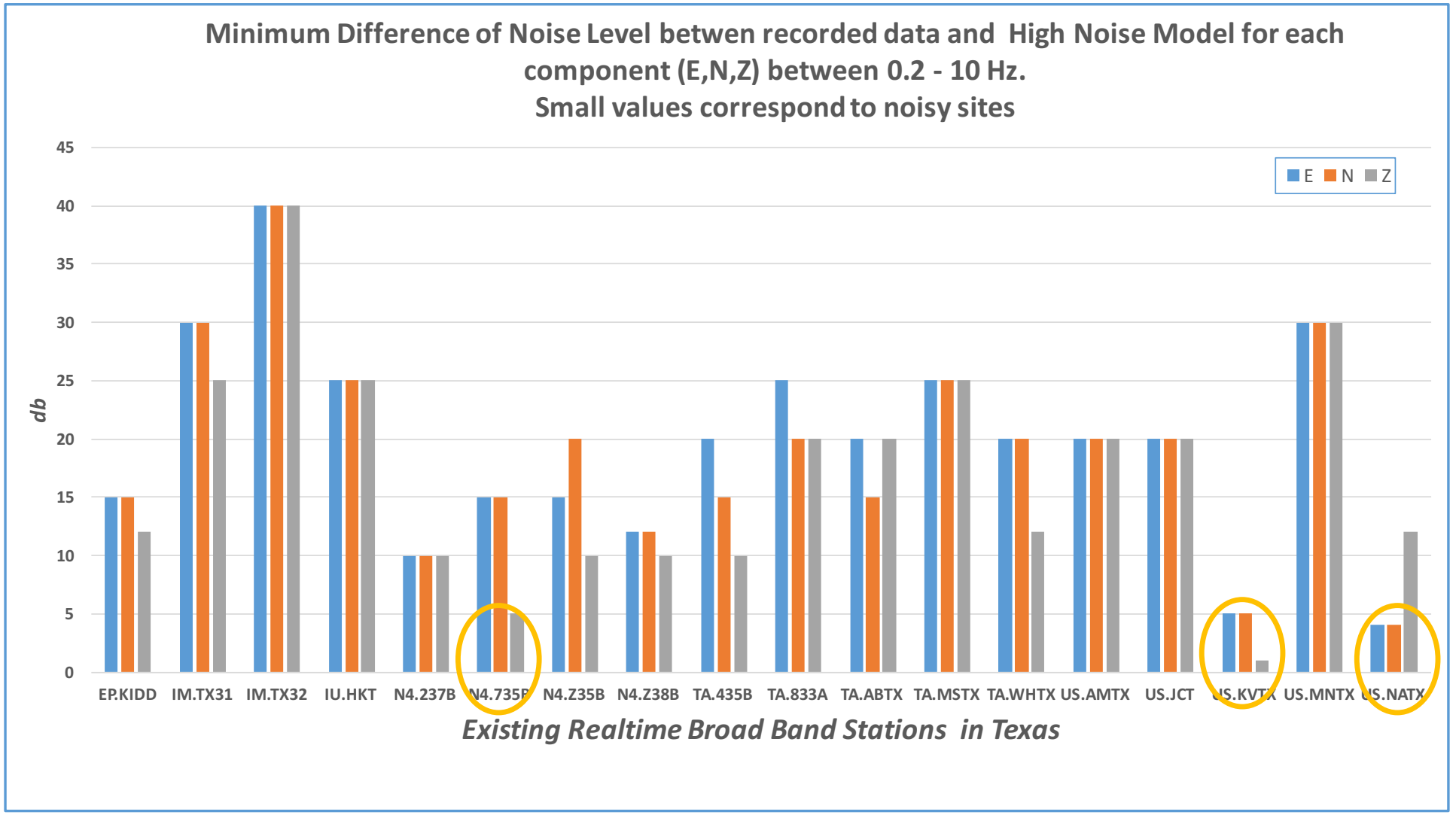
Existing Broad Band Station Metadata

Station Name	Owner	Operating Since	Latest Sensor Update	Instrument	Operating by
EP.KIDD	UTEP Seismic Network	10/8/09	10/8/09	CMG-3T, 120 s, 1500 V/m/s-RT130, gain 1, 40 sps	UTEP
IM.TX31	International Miscellaneous Stations	1/3/72	11/18/13	KS54000=TX31=AIM24S_KS54K=TX31	TXAR Array, Lajitas, TX
IM.TX32	International Miscellaneous Stations	1/24/70	4/11/06	KS5400	TXAR Array, Lajitas, TX
IU.HKT	Global Seismograph Network (GSN - IRIS/USGS)	7/21/95	2/3/16	Streckeisen STS-1VBB w/E300	Albuquerque Seismological Laboratory (ASL)/USGS
N4.237B	Central and EAstern US Network	2/6/14	2/5/14	Streckeisen STS-2.5/Quanterra 330 Linear Phase Com	UC San Diego
N4.735B	Central and EAstern US Network	2/27/14	2/27/14	Streckeisen STS-2 G3/Quanterra 330 Linear Phase Co	UC San Diego
N4.Z35B	Central and EAstern US Network	2/10/14	2/10/14	Streckeisen STS-2 G3/Quanterra 330 Linear Phase Co	UC San Diego
N4.Z38B	Central and EAstern US Network	2/12/14	2/12/14	Nanometrics Trillium 240 Sec Response sn 0-399/Qua 330	UC San Diego
TA.435B	USArray Transportable Array (NSF EarthScope Project)	1/15/10	1/26/16	Guralp CMG3T/Quanterra 330 Linear Phase Composite	IRIS Transportable Array (IRIS_TA)
TA.833A	USArray Transportable Array (NSF EarthScope Project)	12/4/09	10/16/15	Streckeisen STS-2 G3/Quanterra 330 Linear Phase Co	IRIS Transportable Array (IRIS_TA)
TA.ABTX	USArray Transportable Array (NSF EarthScope Project)	2/12/09	10/16/15	Streckeisen STS-2 G3/Quanterra 330 Linear Phase Co	IRIS Transportable Array (IRIS_TA)
TA.MSTX	USArray Transportable Array (NSF EarthScope Project)	4/23/08	11/23/15	Streckeisen STS-2 G3/Quanterra 330 Linear Phase Co	IRIS Transportable Array (IRIS_TA)
TA.WHTX	USArray Transportable Array (NSF EarthScope Project)	2/11/09	10/16/15	Streckeisen STS-2 G3/Quanterra 330 Linear Phase Co	IRIS Transportable Array (IRIS_TA)
US.AMTX	United States National Seismic Network	9/29/02	5/2/11	STS2-I=80630=Gen=Q330SR=3521	Albuquerque Seismological Laboratory (ASL)/USGS
US.JCT	United States National Seismic Network	2/3/00	6/21/11	STS2-I=80219=Gen=Q330SR=0884	Albuquerque Seismological Laboratory (ASL)/USGS
US.KVTX	United States National Seismic Network	6/16/06	5/2/11	STS2-I=80434=Gen=Q330SR=1261	Albuquerque Seismological Laboratory (ASL)/USGS
US.MNTX	United States National Seismic Network	5/29/03	5/2/11	STS2-I=10440=Gen=Q330SR=3716	Albuquerque Seismological Laboratory (ASL)/USGS
US.NATX	United States National Seismic Network (USNSN)	5/12/04	7/8/15	Streckheisen STS2-I=80406=Gen=Q330SR=3522	Albuquerque Seismological Laboratory (ASL)/USGS

Metadata information are provided through IRIS

Noise Level of Existing Broad Band Stations



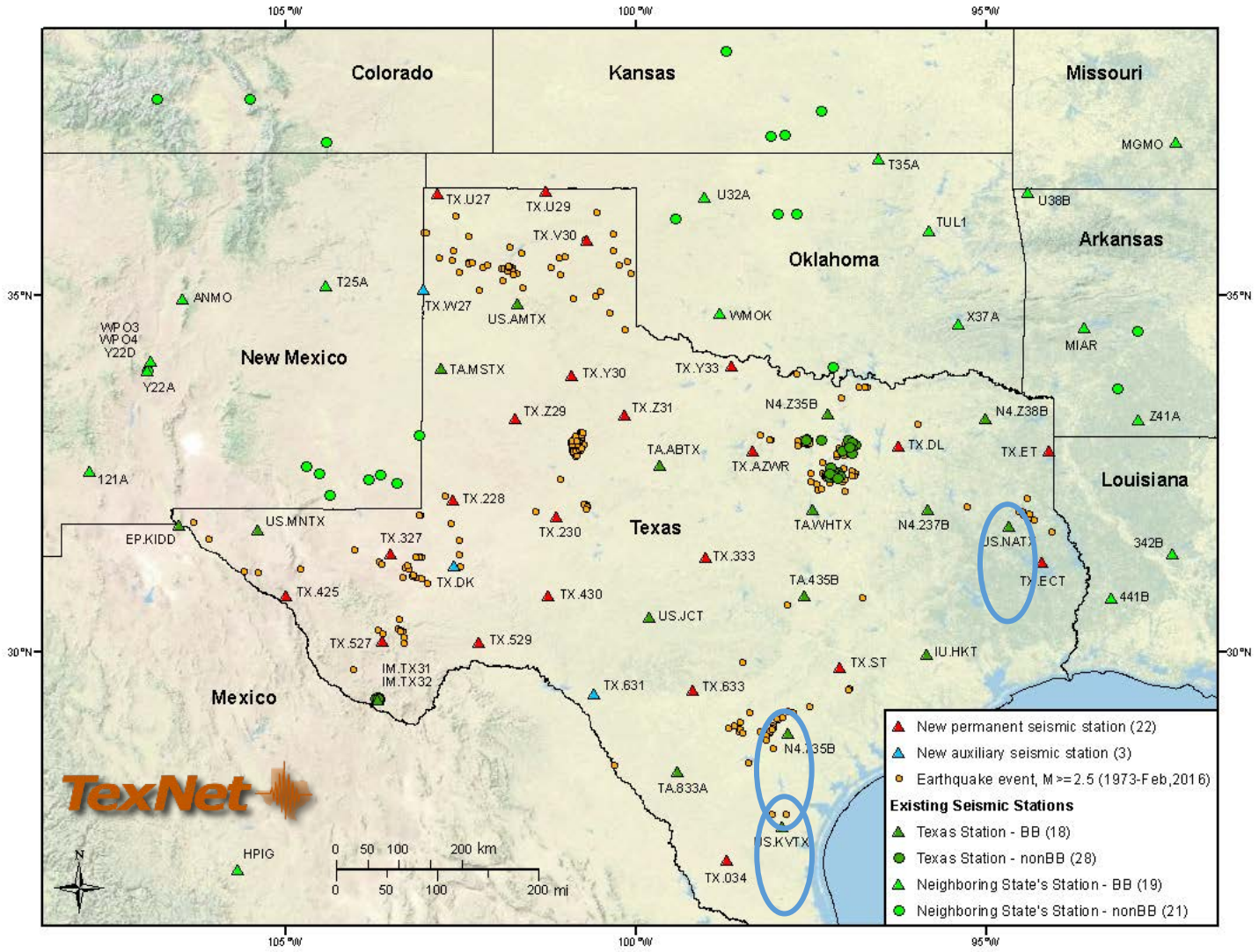
Noise level information are provided from IRIS

Noisy Existing Stations

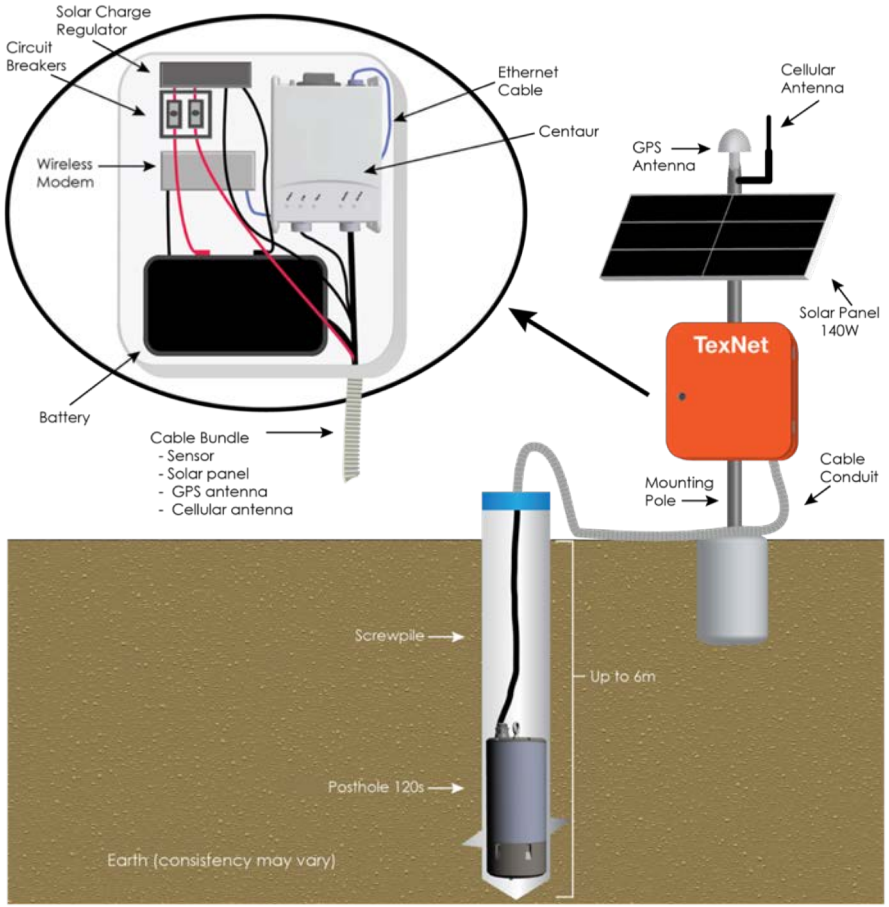
- Stations with high noise level

Reasoning:

- Soil Conditions
- Human Activity



TexNet Permanent Station Setup

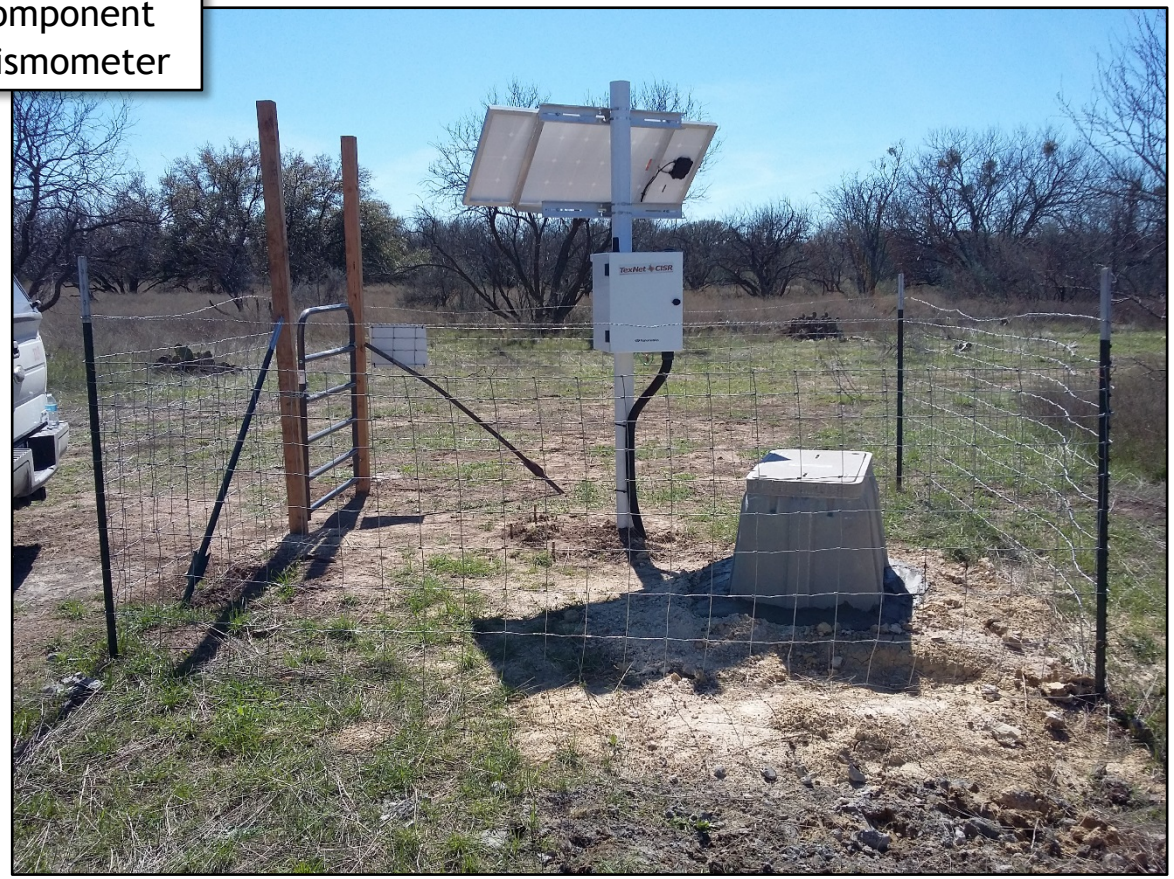


Permanent Stations :

- pole-mounted hardware
- 6 Channel Datalogger
- Wireless Modem
- 200Ah Battery
- 150W Solar Panel, and
- 120sec – 3 Component Post-Hole Seismometer

Hardware:

- 22 Trillium PH with centaur DL
- 1 PH Radian with minimus DL
- 1 BH Radian with minimus DL (TBD)



TexNet Portable Station Plan

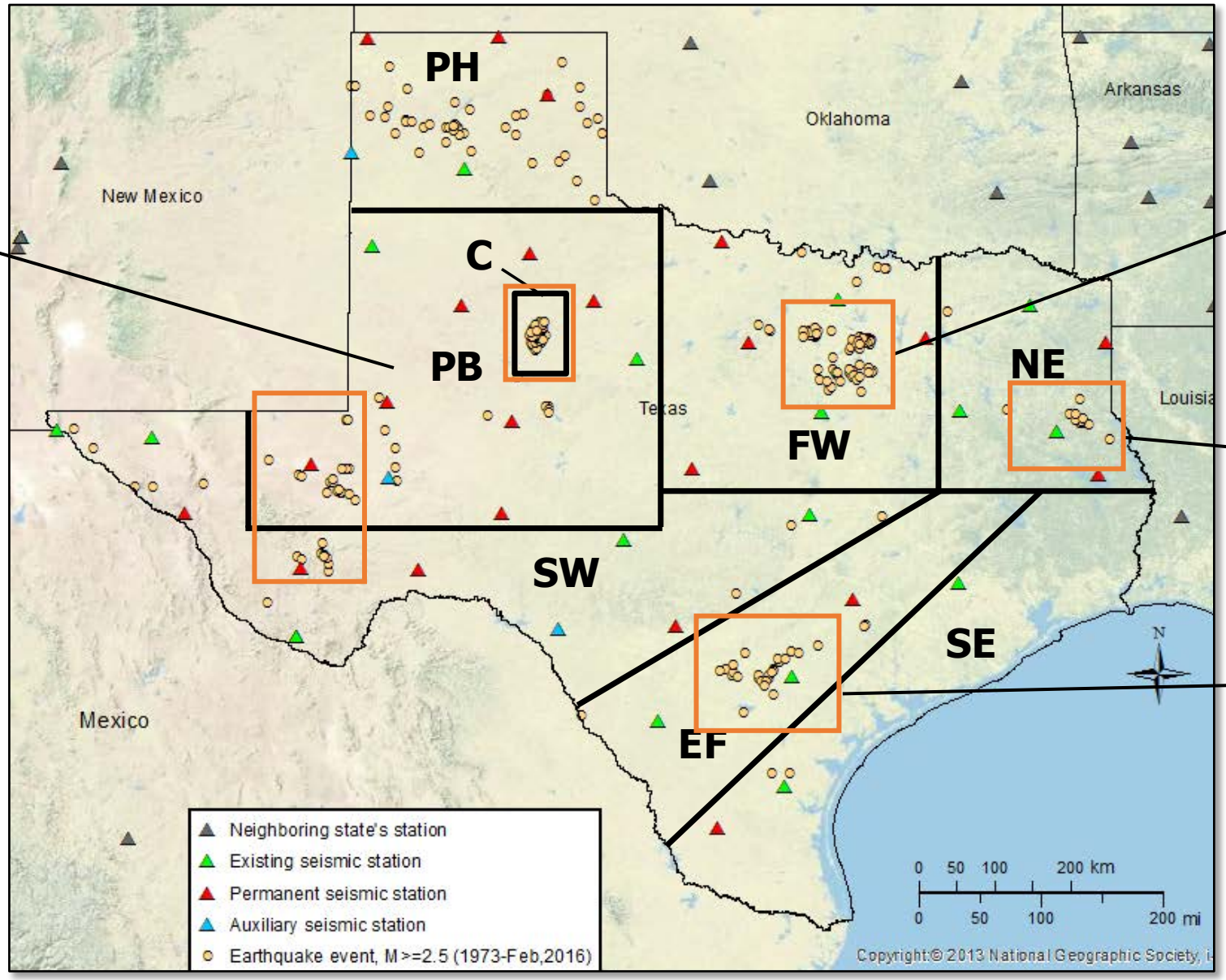
Permian Basin
2016-2017
- 7 stations near Pecos
- 7 near Snyder (Cogdell Field)

2018
- 9 near Pecos and elsewhere

UT-BEG - rapid deployment reserve
2016-2017
- 3 stations

2018
- 3 stations

(other deployed portable stations can be repositioned to augment the rapid deployment reserve)



Ft Worth Basin
2016-2018
- 12 stations to be adjusted depending on seismicity trends and availability of other sensors

Northeast Texas
2016-2017
- 0 stations

2018
- 3 stations

Eagle Ford
2016-2017
- 4 near Fashing

2018
- 6 near Fashing and elsewhere

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Portable Station Setup

Portable Stations :

- direct burial installations
- pole-mounted hardware
- 6 Channel Datalogger
- Wireless Modem
- 200Ah Battery
- 150W Solar Panel,
- 3-component, 20 sec seismometer
- 3-component accelerometer

Hardware:

- 36 trillium compact and titan PH with centaur DL
- 1 CMG40T with minimus DL
- 5 CMG40T with minimus+ DL (TBD)
- 8 CMG3T (TBD) - UH
- 25 MBB-2 with minimus DL (TBD) - UTIG
- 18 CMG5T/CMG5TC – UAF/AEC (TBD)

Texas Seismological Network

23 New Permanent Stations
17 Existing Stations
3 New Auxiliary Stations

43 Station Backbone for Texas

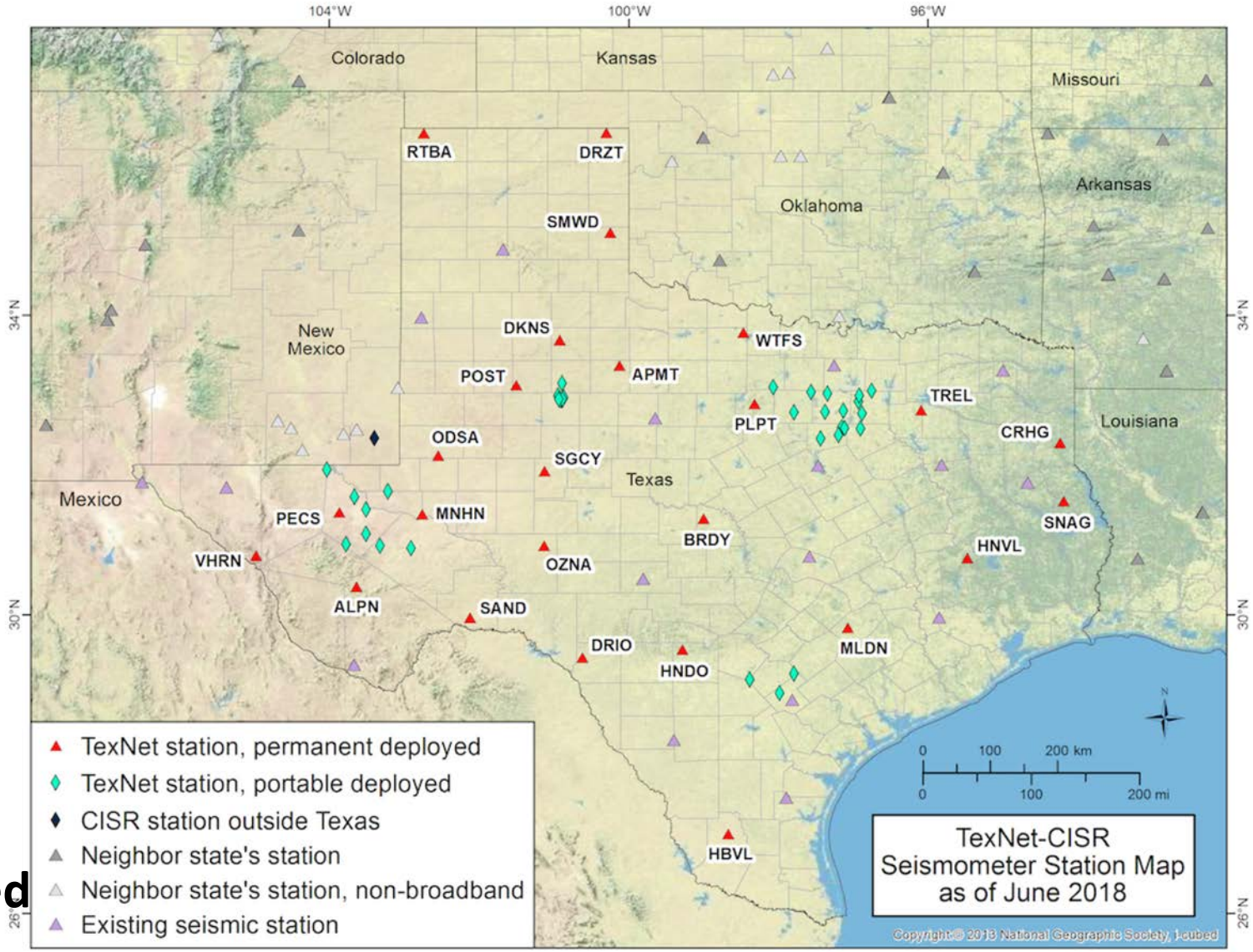
33 Portable Stations deployed

- 15 (14) deployed in the DFW area
- 7 are deployed in the Snyder area
- 8 (7) deployed in Permian Basin area
- 3 (2) deployed in the Eagle Ford area

1 Station deployed in NM

2 Portable Stations currently available

6 Portable Stations soon to be delivered



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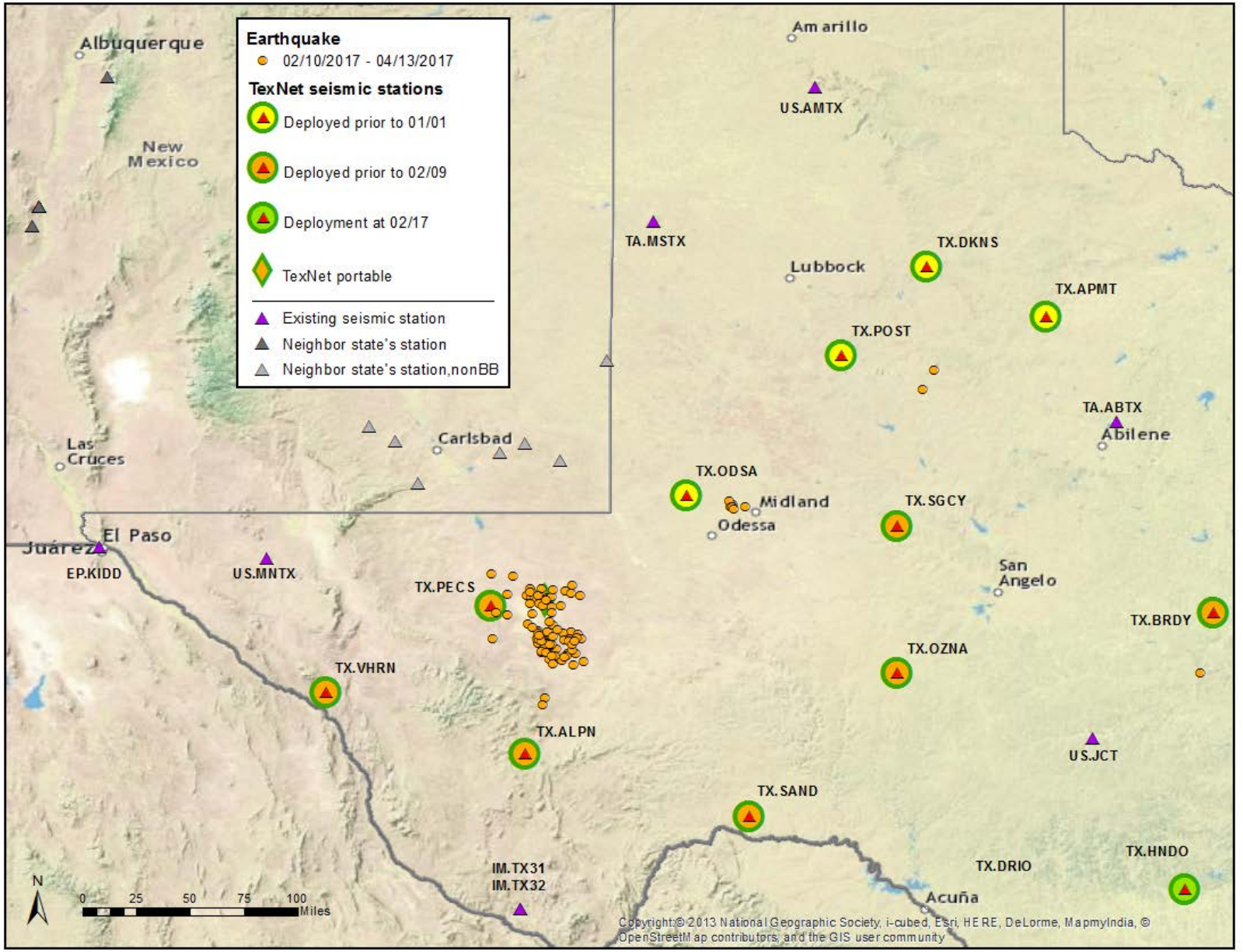
Reported Seismicity Through Time

Earthquakes in December 2016, before TexNet deployment

Earthquakes in January 2017, after 4 TexNet Station deployments

Earthquakes from 02/10/17 to 04/13/2017* after 12 TexNet Station deployments

*Earthquake Catalog does not include events of March 16-31



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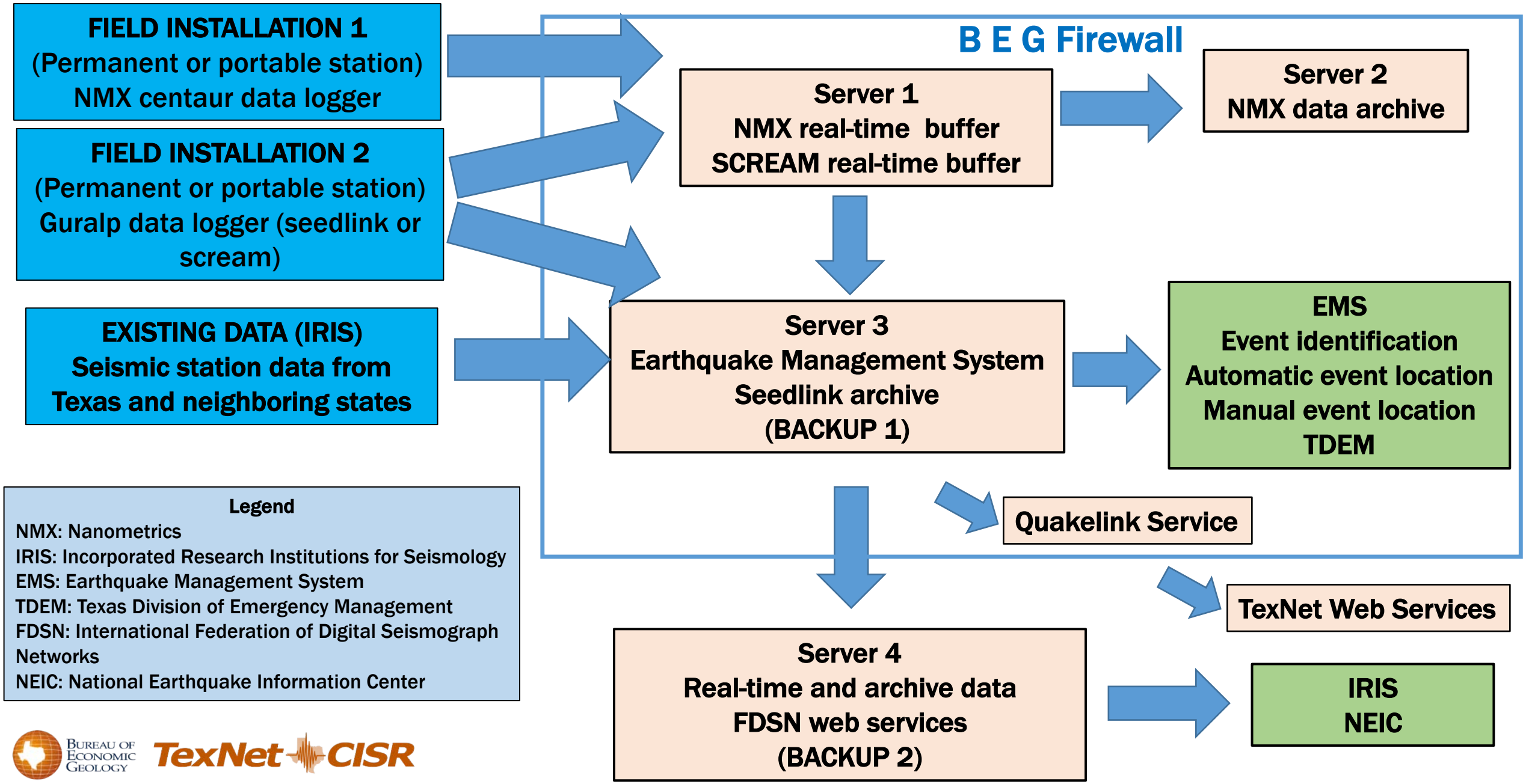
TexNet HUB



Legend

NMX: Nanometrics
IRIS: Incorporated Research Institutions for Seismology
EMS: Earthquake Management System
TDEM: Texas Division of Emergency Management
FDSN: International Federation of Digital Seismograph Networks
NEIC: National Earthquake Information Center

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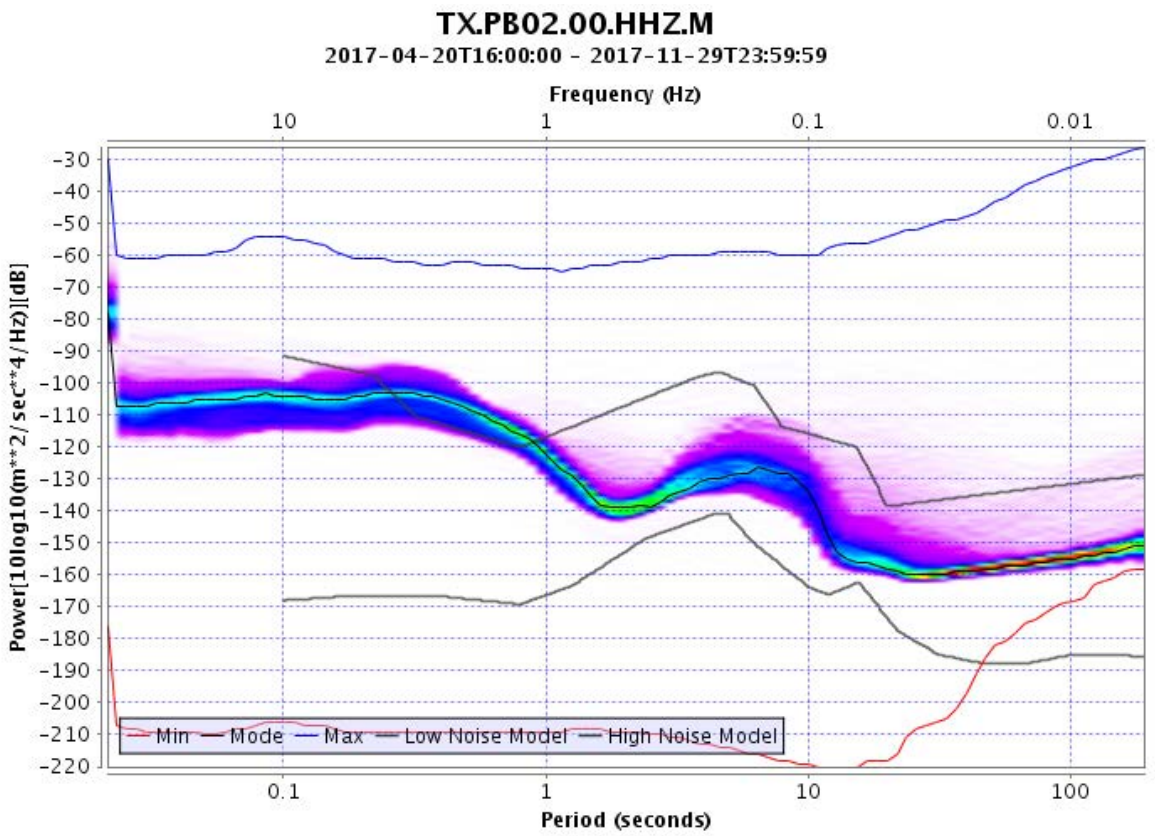
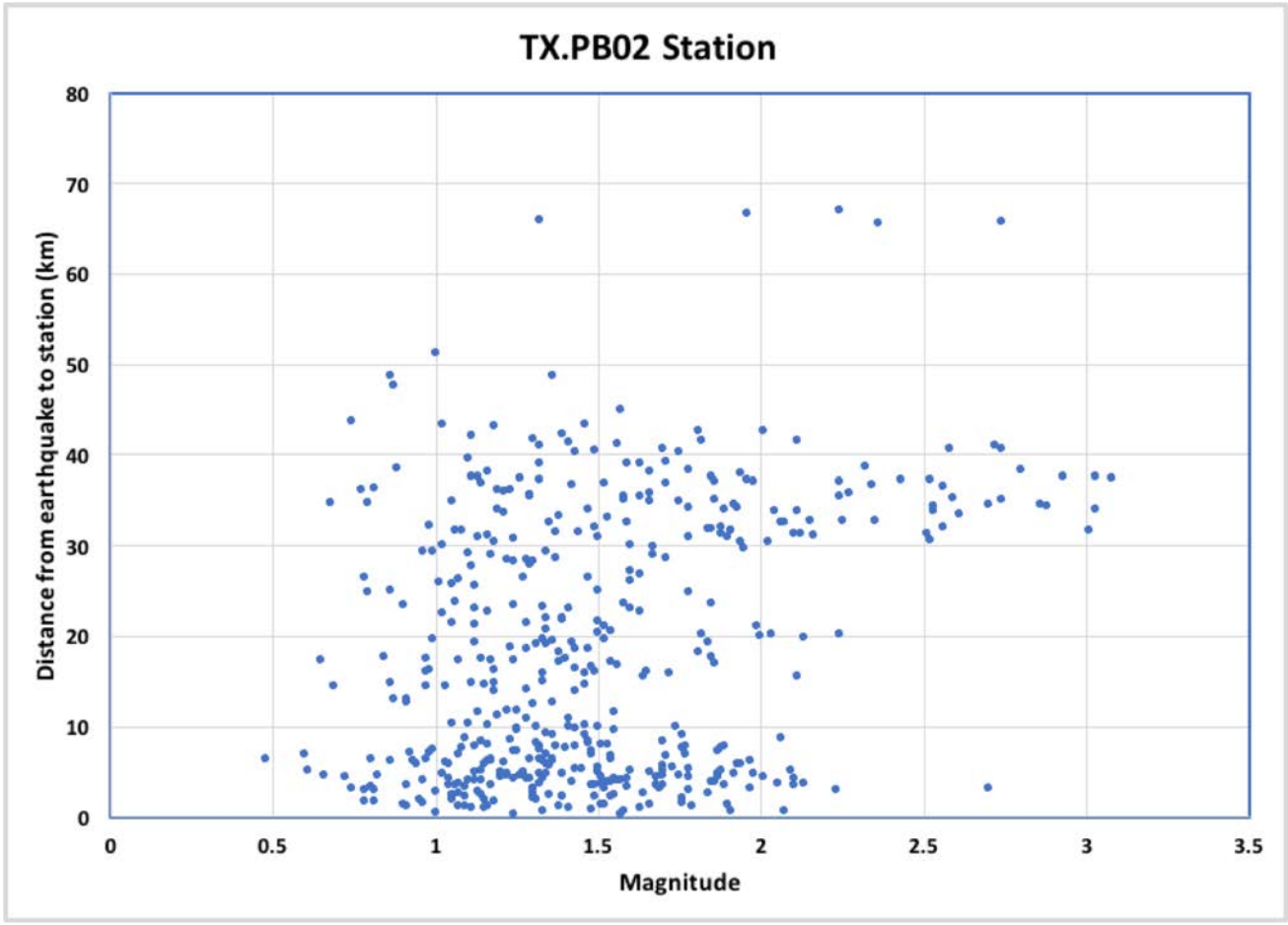
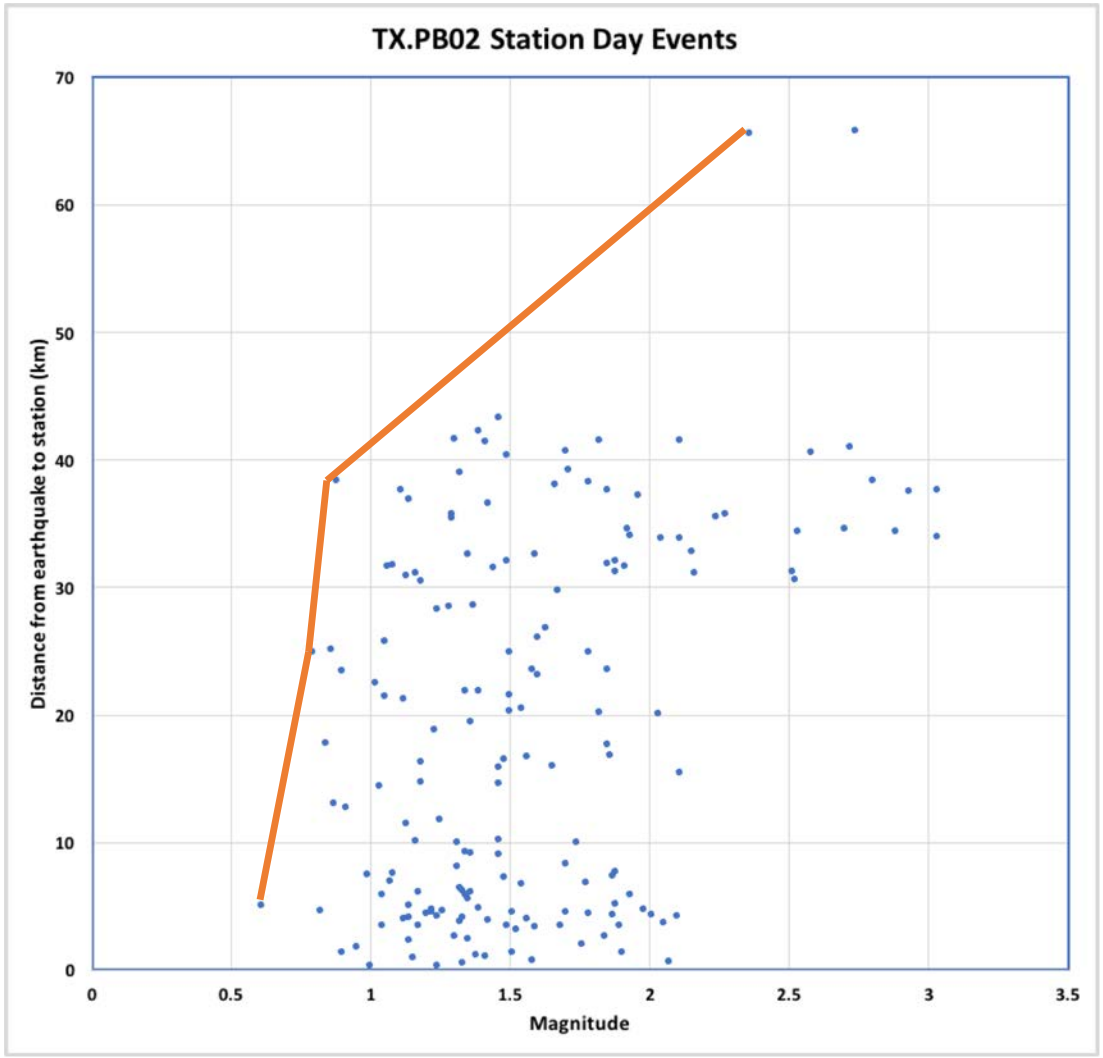
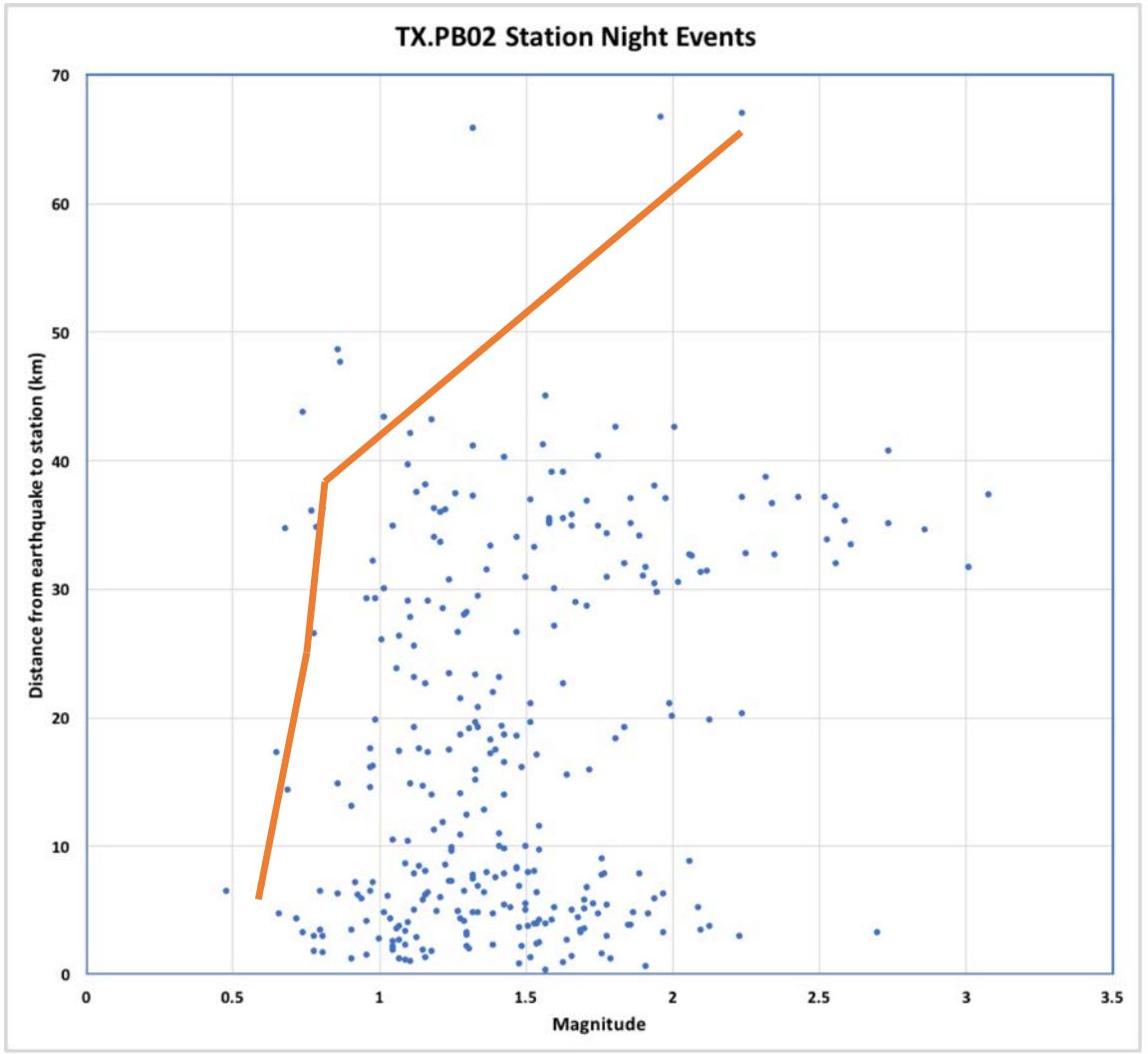
Noise Analysis (Urban/Industrial Site)





Day versus night detectability in a noisy site





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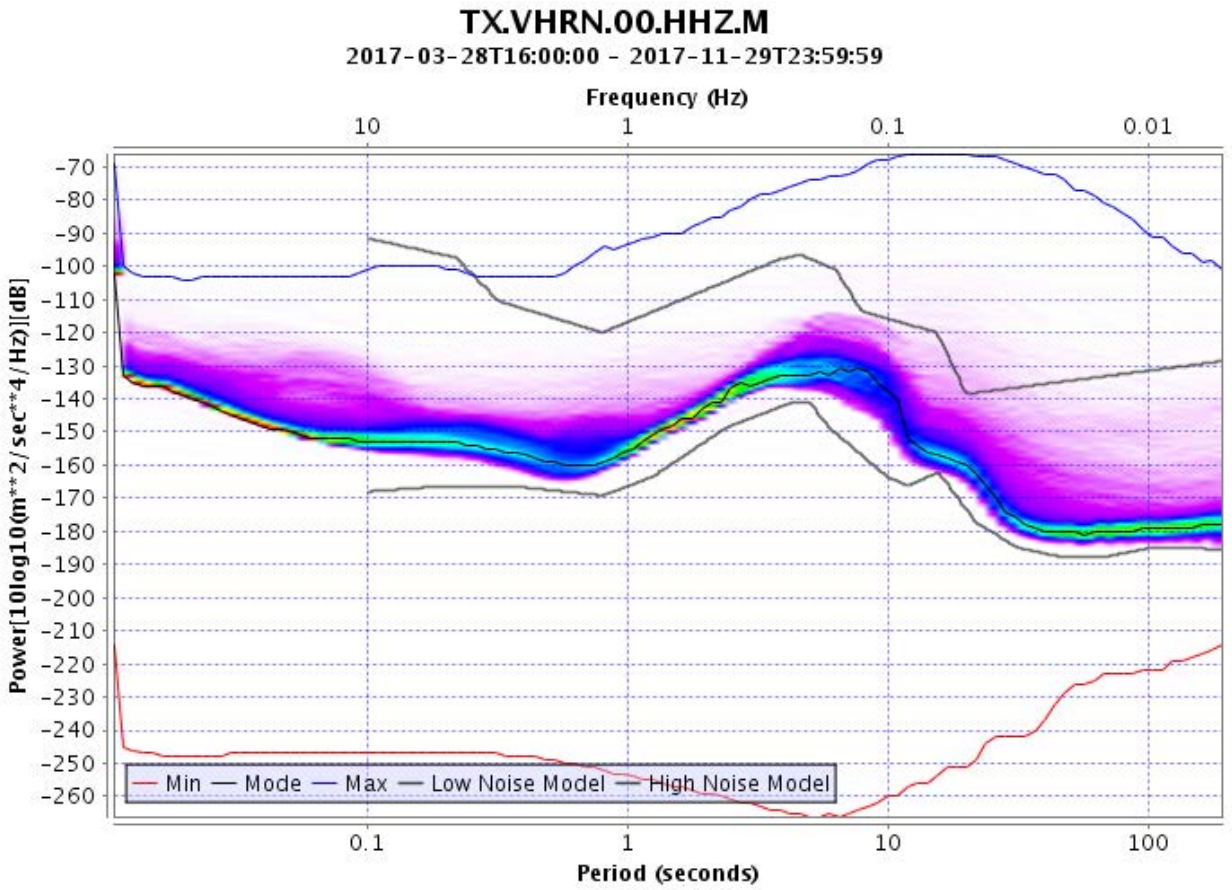
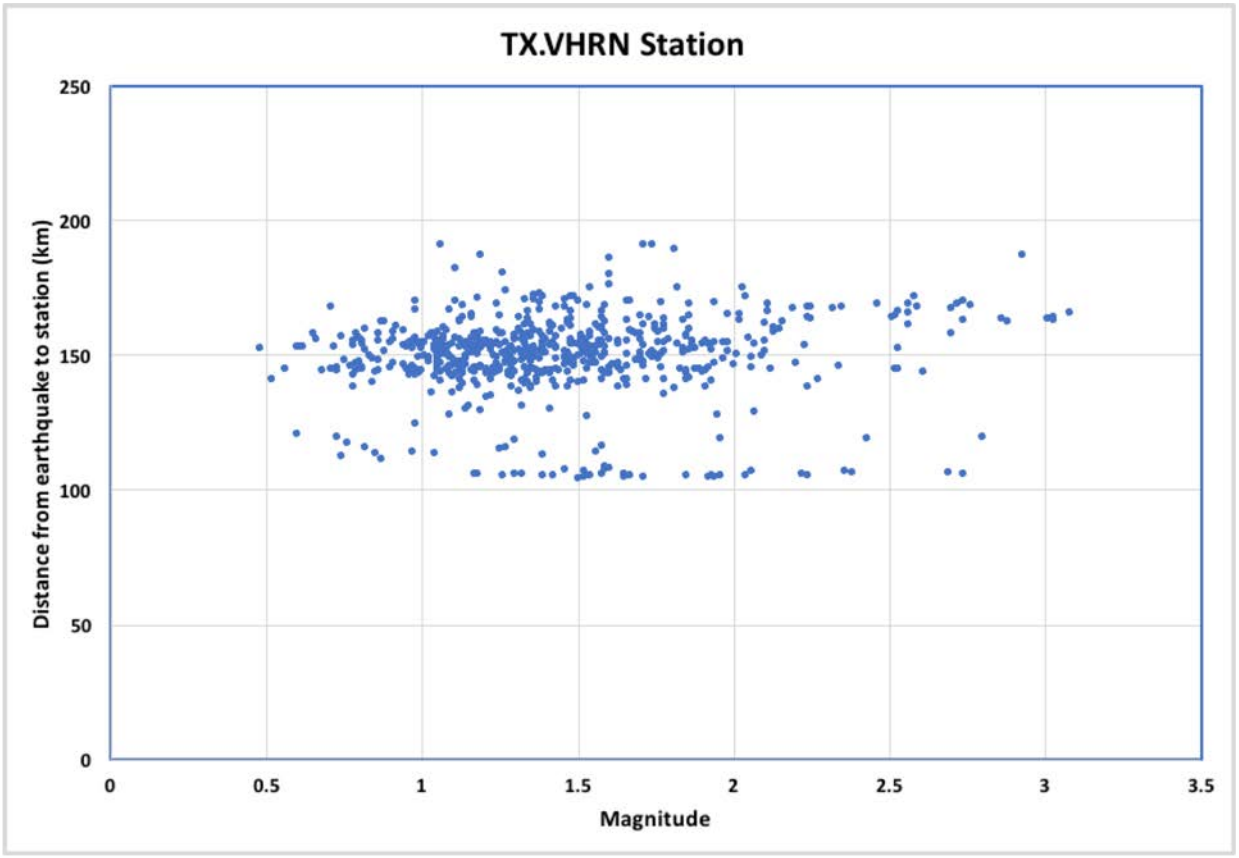
Detectability of low noise sites





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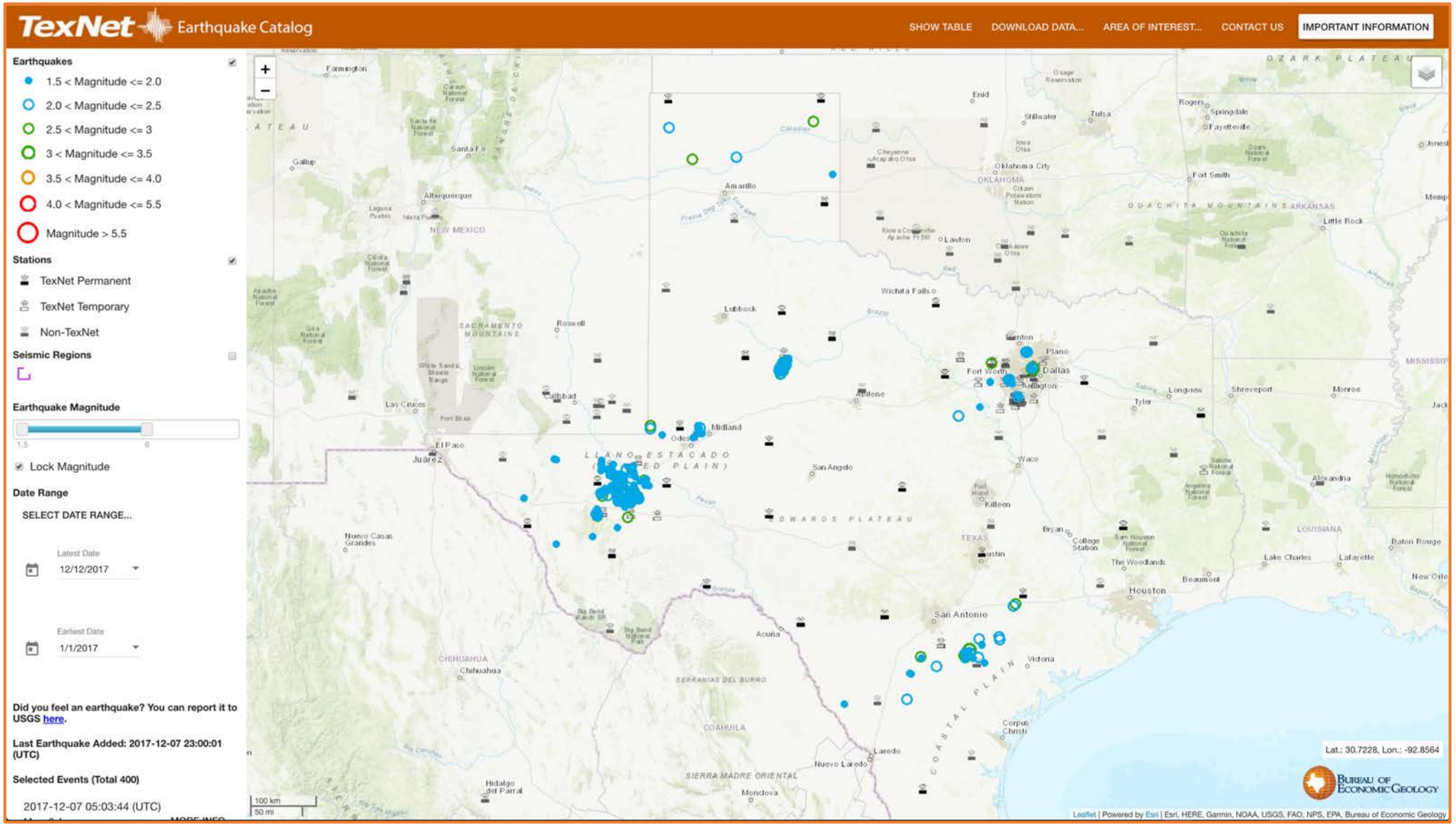
http://www.beg.utexas.edu/texnet/catalog



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Questions?