Hydraulic Fracture Notices 2016-Present

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Induced Seismicity Department



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OGS complete catalog to hydraulic fracture notices – temporal match

Method – changes due to new form creation – tighter resolution

- Map well trace, EQ Events (Oklahoma Geological Survey Catalog)
- Search EQ events: 5km from trace
- EQ event occurred:
 - (on or after start date) & (on or before end date+ 7 days)



OCC Seismicity Dept - Operations Toolbox

(USGS/OGS Catalog & FracNotice)



Toolbox Spatial Temporal Spreadsheet

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4	A	В	C		D	E	F	G	Н	1	J	K	L	N
1 FIC)	(Multiple Items) 📝												
2														
3		1/0 19181			N7 - 20	2.5	50 32		12 12	50 X	Data			
4 orig	gintime 💌	API 🔽 🖸	DpName	▼ WellName	Coun	y 🔹 st	tatus 💌 🗸	21	C_1_Cell	C1_Phone	Count of event_id	Min of magnitude	Max of magnitude	e
5 6	2/5/2019	3601123957	DEVON ENERGY	CIDOPPELGANGE	Bla	ine 🗉	Preliminary	- Heather Lacy	-406693898		1	2	1	2
6		□3501123988	DEVONENERGY	DOPPELGANGE	Black Black	ine 🗉	Preliminary	Healher Larry	= 3056935955		2	2		2
7		B 3501 123989 (DEVON ENERGY	DOPPELGANGE	Bla	ine 😑	Preliminary	- Healher Lacy	= 405693595		1	2		2
8		B 3501124003	DEVONEMERGY	-BARAKEN 33_28-1	GNETOW SELX	ine 😑	Preliminary	-Heather Lacy	-405693595		1	2	L. I	2
9		835011240053	DEVON ENERGY	KRAKEN 33_28-	6N=10V/ 6HX Bla	ine 😑	Preliminary	- Fleather Lacy	-14056936865		1	2	5	2
10		B 3501124014	DEVONENERGY	_RRAKEN 33_28-1	GNE10VV #HOX Bla	ine 😑	Preliminary	- Heather Lacy	= #05693695		1	2		2
11		:■3505124447 (ROAN RESOURCESILLC	- 100M KING 9-4-9-	⊟ Gr:	ady 🖂	Preliminary	- WINGE TUZONE	- 205-641-69		1	1.9	1. 1.	9
12		 D505124448 	ROAN RESOURCES LLC	- DOM KING 94-9-	⊡ Gr:	ady 😑	Preliminary	- VINCE THE	- 405-641-55		1	1.9	1	9
13		3605124477	ROAN RESOURCES LLC	ETIL, HAVE ANOTH	ER 9 4 9 6 3 0 7 H ■ Gr	ady 🗉	Preliminary	-MINCE TIZZONE	-306-541-59		<mark>. 1</mark>	1.9	1. 1.	9
14		B505124478	ROAN RESOURCES LLC	CILL HAVE ANOTH	ER 9-4-9-6 41/1XH	ady 🖂	Preliminary	-NINCE TIZZCHIE	= 105-641-59		1	1.9	1.	9
15		E 3505124495 €	ROAN RESOLIRCESTEC	-300M KING 8-5-9-	∃ MXH ■ Gr	ady 😑	Preliminary	- MINCE TRZOME	- 405-541-59		1	1.9	1. 1.	9
16		= 350512/496 C	ROAN RESOURCES LLC	DOM KING 8-5-9-	🗟 🖓 🖂 🗇 🗇	ady 😑	Preliminary	-WINCE TIZZONE	- 405-641-59		1	1.9	1.	9
17 6	2/4/2019	C 350/326290 /	SK NEMAHA LEC	ESKETT 17-M3NH	🗏 Kir	gfisher 😑	Reviewed	-BAURABH AGA	RVVAL = 113289174		1	3.1	3.	1
18		B 35073126384 §	SKINEMAHA LLC	BRETT 17-M6NH	⊟ Kir	gfisher 😑	Reviewed	SAURABHIAGA	RIVAL E713299171		1	3.1	3.	1
19 6	32/2/2019	· · 3505124447 (ROAN RESOURCES ILC	- IQON KING 9-4-9-	⊟ Gr:	ady 🖂	Reviewed	-WINCE TUZONE	-305-641-59		1	1.1	i <u>1</u> .	1
20		- 350512448	ROAN RESOURCES LLC	- DOM KING 94-9-	⊡ Gr:	ady 😑	Reviewed	-WINCE TIZZENIE	-405-641-55		1	1.1	1. 1.	1
21		■ 3605124477 (ROANRESOURCESILC	EIL HAVE ANOT	■ Gr:	ady 🗉	Reviewed	-MINCE TIZZENIE	-106-541-59		1	1.1	i <u>1</u> .	1
22		C 3505124478 4	ROAN RESOURCES LLC	- ANOTH	ER 9-4-9-6 41/1XH	ady 🖃	Reviewed	-NINCE TIZZCHIE	E \$105-641-59		1	1.1	i <u>1</u> .	1
23		3505124495 (ROAMRESOURCESTEC	-300M KING 8-5-9-	∃ MXH ⊟ Gra	ady 😑	Reviewed	- MINKE TRZAME	= 305-541-59		1	1.1	i <u>1</u> .	1
24		G 3505124496 .	ROAN RESOURCES LLC	DOM:KING 8:5-9-	😑 Gra	ady 😑	Reviewed	-WINCE TIZZONE	-405-641-59		1	1.1	i <u>1</u> .	1
25		E 8505124501	EAMINO NATURAL RESOUR	CESTLC ENVAYMANTISDA	🖃 0907 12-13 10 H	ady 🗏	Reviewed	- Осна Сенств	-820-405-27		1	1.1	i <u> </u>	1
26 8	2/1/2019	⇒3501123984 §	DEVON ENERGY	- DOPRELGANGE	e Bla	ine 🗉	Reviewed	-Heather Lacy	E #056936951		1	2.1	2.	1
27		3501123987	DEVON ENERGY	- DOPRELGANGE	Bland Bland	ine 🖂	Reviewed	-Heather Lacy	- 4056935959		1	2.1	2	1
28		-0501123988	DEVONIENERGY	DOOPPELGANCE	e a general and the second sec	ine 😑	Reviewed	-Triesther Lacy	- 405693555		2	2.1	2.	1
29		C 3501123959 (DEVON ENERGY	DDOPPELGANGE	E = 9-1614-10-2710X _ ⊟ Bla	ine 😑	Reviewed	Fleather Lacy	-105693555		1	2.1	2.	1
30		B3501123996 8	DEVON-ENERGY	-XRAKEN 33_28-1	Bla Bla	ine 😑	Reviewed	-Healher Larry	-3056935955		1	2.1	2.	1
31		B 350 1 1240//33	DEVONIENERSY	BARAKEN 33_23-1	Blatter Blatter	ine 😑	Reviewed	- Heather Lacy	E 405693595		1	2.1	2.	1
32		B 35011240053	DEVONENERSY	EKRAKEN 33, 26-1	GNR10AV/GRAX	ine 😑	Reviewed	-Heather Lacy	-405693595		1	2.1	2.	1
33		03501124044	DEVON ENERGY	EKRAKEN 33_28-	6N#10W/4HX Bla	ine 😑	Reviewed	-Triesther Lacy	-M056936865		1	2.1	2.	1
34		3500722103	BP AMERICA PRODUCTION	COMPANY PAUTREY SHITW	⊟ Mo	clain 😑	Reviewed	Chris Hines	_7 13-553-78.		1	2.7	2.	7
35 😑	1/29/2019	B50512444Z	ROAVIRESIQUIRCESILLC	EDON KING 9-4-9-	⊟ Gr:	ady 🖂	Reviewed	NINCE IUZIONE	0405-641-59		1	2.3	2.	3
36		D 150512448	ROAN RESOURCES LUC	DOW KING 9-4-9-	⊡ Gr:	ady 😑	Reviewed	- WINCE THERE	-205-641-55		1	2.3	2.	3
37		B36054244771	ROAMBESOURCESILLC	EIL HAVE ANOTI	■ Gr:	ady 😑	Reviewed	WINCE TIZZENIE	2005-841-59		1	2.3	2.	3
38		3505124478	ROAN RESOURCES LLC	CILL HAVE ANOT	ER S 4 S 6 4 AXH E Gra	ady 😑	Reviewed	- VINCE TIZZONE	-305-641-59		1	2.3	2.	3
39		B 35051244953	ROAMRESOURCESTEC	DON KING 8-5-9-	⊟ Gra	ady 😑	Reviewed	- WINCE TIZZOME	E 305-541-59		1	2,3	2.	3
40		E 0645 1244 96 (ROAN RESOURCES LLC		⊟ Gra	ady 😑	Reviewed	MINCE MZONE	■405-641-59		1	2.3	2.	3
41		E 8505124501 a	- RAMINO NATURAL RESOUR	CES LLC ENVAYMANTISDA	E 0907 12-13:1MH B Gr	ady 😑	Reviewed	-DoelGarcia	E\$20-405-27		1	2.3	2.	3
42 🖃	1/26/2019	B 3505124364 (NEWHELD EXPLORATION C	OMPANY BRAYLOR 755151	Gra	ady 🖃	Reviewed	LOYDJOHNSC	N018.978:00		3	1	. 2.	2
43		E 3505124973 (NEWFIELD EXPLORATION C	OMRANY DRAYLOR 7.5-164	⊟ Gra	ady 🖂	Reviewed	- LOYD JOHNSE	N -918.978-08		3	1	. 2.	2
44		-0505121374	NEWFIELD EXPLORATION C	OMPANY OXAYLOR 7-5-15-1	⊟ Gr:	ady 😑	Reviewed	- LLOYD JOHNSC	N = \$18.378-0.3		3	1	. 2.	2
45			MEWFIELD EXPLORATION C	OMPANY CRAYLOR 7-5-15-1	⊟ Gr:	ady 🗉	Reviewed	ELCYDJOFISC	E S 18 978-08	105 263-7425	3	1	2.	2

Well Correlations



SUMMARY OF REVISED WELL COMPLETION SEISMICITY PROTOCOL*

Terms: Oil and Gas Conservation Division (OGCD) Induced Seismicity Department (ISD) Oklahoma Geological Survey (OGS)

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Operators' actions following seismic activity within 5 km (3.1 miles) of hydraulic fracturing operations:

- If, during active operations, the operator detects a seismic event within the monitoring area at least 2.0 ML but less than 2.5 ML, the operator shall implement its seismicity response plan.
- If magnitude is at least 2.5 ML but less than 3.0 ML the operator will notify the ISD of the event.
 - If operator has not initiated its seismicity response procedures prior to a 2.5 ML event, the operator shall pause hydraulic fracture operations for 6 hrs and a technical conference call will be held with ISD staff and operator regarding proposed seismicity response procedures.
 - If operator has initiated its seismicity response procedures prior to a 2.5 ML event, a technical conference call will be held with ISD staff and the operator regarding proposed seismicity response procedures, if any, and steps ISD deems necessary.
- If magnitude is at least 3.0 ML but less than 3.5 ML:
 - Operator shall pause hydraulic fracture operations for 6 hours and a technical conference call will be held with ISD staff and operator regarding proposed seismicity response procedures.
 - Upon agreement between operator and OGCD staff regarding mitigation practices and reduced seismic activity, operator will be permitted to resume with a revised completion procedure.
- If magnitude is 3.5 ML or greater:
 - Operator immediately suspends operations.
 - In-person technical conference held with OGCD staff and operator to examine whether operation can resume with changes.

Well Completion Protocol

• Well Completion Protocol issued December 2016

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- Update to Protocol with current action levels issued February 2018
- Requires active seismic monitoring within completion AOI
- Seismic mitigation plans can be requested from operators at any time
- Completion data requested after pauses or shutdowns enforced



Induced Seismicity Department

OGS Earthquakes 2015-Present



Induced Seismicity Department

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Earthquake Count M2.7+ OGS Catalog | Continuous (2015-2019)

2015: 5.40 **2016:** 3.60 **2017:** 1.70 **2018:** 1.10 **2019:** 1.49



origintime (Month)

Earthquake Count M2.7+ OGS Catalog | Continuous (2015-2019)

2015: 5.40 **2016**: 3.60 **2017**: 1.70 **2018**: 1.10 **2019**: 1.49



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Earthquake Count M3.0+ OGS Catalog | Continuous (2015-2019)

2015: 2.48 **2016**: 1.70 **2017**: 0.83 **2018**: 0.53 **2019**: 0.65



origintime (Month)

Earthquake Count M3.0+ OGS Catalog | Continuous (2015-2019)

2015: 2.48 **2016:** 1.70 **2017:** 0.83 **2018:** 0.53 **2019:** 0.65



Template Matching



Preliminary template matching USGS, Golden, CO

Blue histogram #USGS Detections per 2 hours Red histogram #OGS events per 2 hours Dots correlation coefficient template match



Tulsa Stone Quarry

Oklahoma Geological Survey Earthquake Viewer

Attributes

GMT Time: Wed, 23 Jan 2019 21:02:26 GMT Local Time: 1/23/2019, 3:02:26 PM Magnitude: 2.4 Depth: 0 km

Latitude: 36.20716667 Longitude: -95.84133333 County: Tulsa Status: Preliminary

Zoom to

 http://www.occeweb.com/News/2018/05-30-18EARTHQUAKEACTIONSUMMARY.pdf



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Induced Seismicity Department