Kansas Seismicity: Monitoring to Define Earthquake Trends and Characteristics

Exploration Services Participants:
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Dynamic Seismicity in Kansas

History of Seismicity
Current Statewide Network
Sub-Regional Network
Interesting Clusters
What Does It All Mean?
History Studying Earthquakes in Kansas

1867-1976 Historical Intensity Based on Documentation
110 years, 30 felt earthquakes, ~M2.5 to M5

KGS Operated Network
1977-1989
13 years, 171 earthquakes, M0.5 to M4.0

USGS Operated Network
1990-2014
15 years, 18 earthquakes, M2.2 to M3.5
Earthquake Monitoring Restart at the KGS in 2015
Basic Make-up and Operations

- 7 KGS permanent stations—2 vertical & 2 horizontal
- 5 KGS temporary station—1 vertical & 2 horizontal
- 3 USGS stations occasionally used by KGS

2013-2016 Gov Task Force, KGS working with KS Dept of Health an Environment (KDHE) and KS Corp Commission (KCC)

2015-2017 Installed temporary & permanent networks

Real-time
- email alerts
- M ≥ 2

Near-real time
- Waveforms and preliminary catalog open access
- Full catalog (1 week lag, currently 10,213 events)
  - manual analysis of continuous data (M1 locally)
  - M ≥ 1.8 statewide (4,886 events, 2015 to present)

Since 2016 KGS working with KDHE & KCC developing online mapping & real time notifications, both in beta
Ordered Reduction in Fluid Injection

In 2015, the KCC ordered phased reduction in Arbuckle injection within 5 high seismicity zones. Vast potential of microseismic activity to understand and delineate sensitive structures.
Dense networks provide for enhance location accuracy and improves depth determinations

- USGS has more than 20 stations in Kansas, with all but two in southcentral Kansas focused on Harper and Sumner Counties

- Sub-regional (5) initially sponsored by the KCC, but is currently operated and funded by KGS and designed to monitor for any expansion in the two county area where earthquakes were prominent during 2013-14

- Regional network (7) designed in 2015 to capture elevated seismicity occurring during 2014 and into 2015

- Continued escalation in several earthquake clusters is providing the catalyst for expanding the regional network further with 6 more permanent stations in under sampled areas

Combined Kansas Networks
Seismic Station Installation

Seismic sensor ($15,000)
  - Seismometer
  - Digitizer
Real-time communications ($4,000)
  - cellular modem
  - cellular antenna
  - RTP server
Power ($1,200)
  - 120 watt 12 V solar panel
  - charge controller
  - two deep-cycle marine batteries
Operation ($2,000/year)
  - cell data line
  - annual maintenance
Seismic Station Installation

- charge controller
- cell modem
- digitizer
- batteries
Historical Compared to New Normal

Nearly 150 years of consistent seismicity began abruptly transitioning in 2013

Only locating more earthquakes because more stations

1867 - 2012

1977-2009 (33 years) there were 35 earthquakes reported > M2.5 and 15 > M3.0

2013 - Today

2010-2013 (4 years) there were 4 earthquakes reported > M2.5 and 2 > M3.0

2014-2017 (4 years) there were 618 earthquakes reported > M2.5 and 178 > M3.0
Trends Along Structures: Some Known, Some Not

Earthquakes can only occur on faults with displacement and aligned with regional stress field.
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Trends Along Structures: Some Known, Some Not

![Map showing earthquake trends along structures with a magnified view of activity in a specific area.]
Trends Along Structures: Some Known, Some Not
Earthquakes can only occur on faults w/displacement and aligned w/regional stress field

structural contours (Arbuckle Group)

Northward migration of earthquakes across Reno County from January 2017 to July 2018
Areas of research with focus on seismicity

Spatio-temporal progression of seismicity into central Kansas (Peterie, et al 2018)

Mapping Arbuckle Group hydrostatic surface and pressure

Arbuckle Working Group is a multiagency effort to more completely characterize the Arbuckle by working across all UIC classes. KGS is lead working with KDHE and KCC.
Areas of research with focus on seismicity

**Seismicity in the Salina Basin**

- Comprehensive Fault Mapping from Published Data
  - Berendsen and Blair, 1986
  - Cole 1976
  - Yarger 1983

**Data Integration**

- 2015-present earthquakes
  - 1983 aeromag w/lineaments

**aeromag w/lineaments interpreted in 1983**

- Earthquakes (2015-present)
Summing Up

• Seismicity in Kansas has dramatically changed since 2013 and continues to change
• Clusters and swarms rarely have the same characteristics
• Seismicity in Kansas (earthquakes above 2.5) spiked in 2015 and has been on the decline since that time.
• Spike in Kansas seismicity was consistent with measured, regional increase in pore pressure in the Arbuckle
  1. As injection volumes decreased, seismicity has declined and Arbuckle pressures have stabilized.
  2. Induced earthquakes occurred as Arbuckle pressures exceed triggering thresholds of critically stressed faults.
  3. Future increases in pore pressure could re-energize seismicity in previously active areas and induce felt earthquakes in areas currently only experiencing micro seismic.
• O&G prices today ~$63/Bbl up from $35 a year ago with rig count currently at 47 last year 33
• Several areas have been identified with potential to produce large numbers of minor earthquakes.
• Kansas networks have proven invaluable, continued operation is dependent on funding.
Trends Along Known Structures

2016-2017

Nemaha Ridge
Sumner
Wellington