Regional Trends and Local Seismicity Near CSTS Member Wells

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Kansas Geological Survey

Fourth Annual CSTS Meeting
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McPherson, KS
Statewide Overview

2020-2021 earthquakes
Statewide Overview

2020-2021 earthquakes
Statewide Overview

2020-2021 earthquakes

- M 0
- M 2
- M 4+
Magnitude Distribution

1180 total
Comparison with 2019

- **2019-2020 earthquakes (1566)**
- **2020-2021 earthquakes (1180)**
Notable Observations

- **First earthquake in TH**
  - M 2.0 on Nov 28, 2020

- **Increase in RS seismicity**

- **Largest events recorded in…**
  - JW: M 4.2 and 4.1
  - MR: M 3.1
  - BU: M 3.0
  - PR: M 2.2
  - ME: 2.0

- **12 M 3+ in Wichita**
Notable Observations

- First earthquake in TH
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- Increase in RS seismicity

- Largest events recorded in...
  - JW: M 4.2 and 4.1
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  - PR: M 2.2
  - ME: 2.0

- 12 M 3+ in Wichita
Monthly Earthquakes

Number of earthquakes

- Statewide network
- South-central KS
- Smoothed average

61 in July 2020

Number of earthquakes
2020 Disposal Volumes

HP Annual Disposal

Harper Co.
2020 Formation Pressure
Formation Pressure Change

2019

2020

pressure change 2019 to 2020

pressure change (psi)
Kiowa County

- KW02
  - north central KW
  - pasture
  - Greensburg
Kiowa County

Arbuckle Group pressure

- Central Kansas Uplift
  - southwest margin
  - west of Pratt Anticline
- Mapped faults
  - None
- Historic earthquakes
  - None
  - Sparse recent seismicity
  - influenced by pore pressure

**historic (1977-2014)**
Kiowa County

- Central Kansas Uplift
  - southwest margin
  - west of Pratt Anticline

- Mapped faults
  - None

- Historic earthquakes
  - None
  - Sparse recent seismicity
  - influenced by pore pressure

Arbuckle Group pressure

- historic (1977-2014)
- KGS network (2015-2018)
Kiowa County

- Central Kansas Uplift
  - southwest margin
  - west of Pratt Anticline

- Mapped faults
  - None

- Historic earthquakes
  - None
  - Sparse recent seismicity
  - influenced by pore pressure
Kiowa County

apparent ~15 psi increase
Kiowa County

- Local Earthquakes (<20 mi)
  - None
  - Pratt M 2.0 ~30 miles

- Subnetwork events
  - None

- Consistent with previous year

KGS/CSTS network (2020-2021)
Reno County

- RN01
  - west of Hutchinson
  - cemetery

- RN03
  - pasture
  - Sand Hills State Park
Reno County

• Geologic Setting
  – CKU and MRS
  – structural low
  – Conway Syncline
  – faults bounding uplifted areas

• Historic earthquakes
  – None (M 3+)
  – Recent seismicity (2015-present)
    ▪ progressed north
    ▪ structural low

Conway Syncline

© KGS network (2015-2020)
Reno County

![Map of Reno County with pressure change over years](image)

![Graph showing pressure change (psi) over years for RN4, RN8, RN9/11, and RN5](image)
Reno County

July 2020 – June 2021
Reno County

- Local earthquakes (w/in 20 mi)
  - 13 events
  - Two distinct clusters
    - Arlington (2, $M$ 1.1 to 1.3)
    - Hutchinson (11, $M$ 0.7 to 2.7)

- Subnetwork events
  - RN03
    - 212, mostly blasts
    - 16 probably microearthquakes
    - $M$ -1.5 to .8
  - RN01
    - 151 (> 500/yr avg.)
    - $M$ -1.5 to 0.3
    - corresponds to Hutchinson cluster
Rice County

- RC02
  - northeast RC
  - pasture
  - Little River

- RC03
  - between Lyons and Sterling
  - pasture
Rice County

- Eastern margin of the CKU
- Mapped structures
  - Geneseo Uplift
  - bounded by faults
- Historic earthquakes
  - M 2.7 in 1981
  - Recently
    - M 1.2 in 2018
    - M 0.8 in 2019

Historic (1977-2014)
Rice County

25-30 psi
Rice County

- Local earthquakes (< 20mi)
  - None

- Subnetwork events
  - RC02: 45 (22/yr avg.)
    - $M_{-1.5}$ to 0.5
    - distance: 1-11 mi
    - Geneseo Uplift
    - small uptick, natural fluctuation?
  - RC03: more than 500
    - 8 mi, regular timing (8 hours)
    - spectral characteristics: likely underground mining blasts
    - discriminate earthquakes
RC03 Subnetwork Event Timing

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Monthly Subnetwork RC03 Events
Ellsworth County

- EW01
  - southwest EW
  - Holyrood
  - pasture, cemetery
Ellsworth County

- Eastern margin of the CKU
- Mapped structures
  - faults
  - anticlines
- Historic earthquakes
  - M 1.7 to 2.0 in 1980s
  - M 1.4 in 2018 (Barton)

Historic (1977-2014)

KGS network (2015-2020)
Ellsworth County

~25 psi
Ellsworth County
Earthquakes in Russell County

_cumulative seismicity 2015-2021_

occurred along the margin of the Central Kansas Uplift
eastward progression from Ellis/Rooks counties
Ellsworth County

- Local earthquakes (< 20 mi)
  - None
  - M 1.3 in BT @ 23 mi
  - M 2.2 in RS @ 24 mi

- Subnetwork events
  - 20 events (5/yr avg.)
  - M < 1
  - 2-11 mi from station
  - pressure increase from the NW?

Historic (1977-2014)
KGS/CSTS network (2020-2021)
McPherson County

- **MP01**
  - northeast of Conway
  - pasture
  - McPherson Valley Wetlands

- **MP02**
  - south of McPherson
  - pasture
  - local church
McPherson County

- Midcontinent Rift System
- Mapped structures
  - Voshell Anticline
  - bounded by faults
- Previous earthquakes
  - M 2.8 in 1981
  - M 1.7 in 1983
  - M 2.6 in 2014
  - Recent seismicity near MP-SA county line

Historic (1977-2014)
KGS network (2015-2020)
McPherson County

~30 psi
McPherson County

- Local earthquakes
  - 11 earthquakes, M 0.4 to M 2.2
  - likely an extension of seismicity in SA along the MGA

- Subnetwork events
  - MP01: 37 events
    - M -1.5 to 0.4
    - 5 mi away
    - corresponds to 2014 earthquake
    - avg. 1 dozen/yr
  - MP02: 47 events
    - M -1.5 to 0.4
    - 6 mi away
    - corresponds to SE cluster
    - avg. 2 dozen/yr

- Increased subnetwork seismicity
McPherson County

![Graph showing earthquake magnitude over years from 2015 to 2022]
Sedgwick County

- SG02
  - south of Wichita
  - pasture
  - local church
Sedgwick County

- Nemaha Ridge
- Mapped structures
  - Valley Center Anticline
  - Likely associated faults
- Previous earthquakes
  - Historic
    - None recorded
    - Felt events in early 1900s
  - Recent seismicity recorded by KGS network
    - Predominantly NE trends
    - Migrated from KS-OK
    - Likely induced

Historic (1977-2014)
KGS network (2015-2020)
Sedgwick County
Sedgwick County

July 2020 – June 2021
Sedgwick County

- Local earthquakes
  - more than 200
  - M 0.7 to 3.9
  - clusters identified previously

- Cheney
  - ~40, largest was M 2.4

- Wichita
  - 161, largest M 3.9

KGS/CSTS network (2020-2021)
Wichita Earthquakes
Sedgwick County

- **Subnetwork events**
  - 30 events
  - M 0.3 to 1.6
  - similar to previous years

- **Distance: 1-11 mi**
  - does not correlate with Wichita events
  - Valley Center anticline

○ KGS/CSTS network (2020-2021)
Butler County

- BU02
  - northeast of El Dorado
  - pasture
  - El Dorado State Park
Butler County

- Nemaha Ridge
- Mapped structures
  - Nemaha Ridge/Humboldt FZ
  - anticlines/synclines
  - mapped faults
- Previous earthquakes
  - 7 historic events (M 3 in 2001)
  - Recent seismicity recorded by KGS network
    - clusters in northern and southern BU

Historic (1977-2014)
KGS network (2015-2020)
Butler County

\[ \text{normalized } P \text{ (psi)} \]

\[ \text{year} \]

\( 25 \text{ psi} \)
Butler County

July 2020 – June 2021
Butler County

- Local earthquakes
  - 43 earthquakes (18 last year, 26 avg.)
  - M 0.9 to 3.0
    - tie for largest
  - most of apparent uptick = Wichita
  - clusters identified previously
  - 3 within 5 mi of well (M <2)

- Subnetwork events
  - 16 (~dozen avg.)
  - 3-11 mi
  - Consistent with mapped faults
    - likely natural
    - possible pressure influence
Butler County

- **Local earthquakes**
  - 43 earthquakes (18 last year, 26 avg.)
  - M 0.9 to 3.0
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- **Subnetwork events**
  - 16 (~dozen avg.)
  - 3-11 mi
  - Consistent with mapped faults
    - likely natural
    - possible pressure influence

○ KGS/CSTS network (2020-2021)
Johnson County

- JO01
  - western JO
  - pasture
  - Olathe Prairie Center

- 2 quarries within 5 mi
  - characteristic waveforms
  - confidently identified
  - not cataloged
Johnson County
Johnson County

- Forest City Basin
  - Nemaha Ridge
  - Bourbon Arch

- Mapped structures
  - no mapped faults
  - NW structural trends

- Seismicity
  - Historic
    - M 0.8 to M 2.1 in 1980s
    - M 3 in 1999
  - Local: none
  - 4 subnetwork events
    - M-0.6-M 0
    - ~5 mi
  - Consistent with previous

- historic (1977-2014)
Summary

• Earthquake rate dropping overall
  – 25% statewide
  – some exceptions
    † Wichita
    † Russell Co
  – evidence of slight increase in last 12 months
  – more earthquakes outside of known clusters
    † Meade
    † Pratt
    † Butler
  – largest events recorded in a few counties

• Formation pressure mostly stable
  – possibly dropping in SG
  – possibly rising in KW, MP
  – because it remains elevated, fluctuations could trigger
    † Wichita possible example

• CSTS network seismicity
  – uptick in Wichita
  – new seismicity in BU
  – uptick in subnetwork events in EW, MP
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