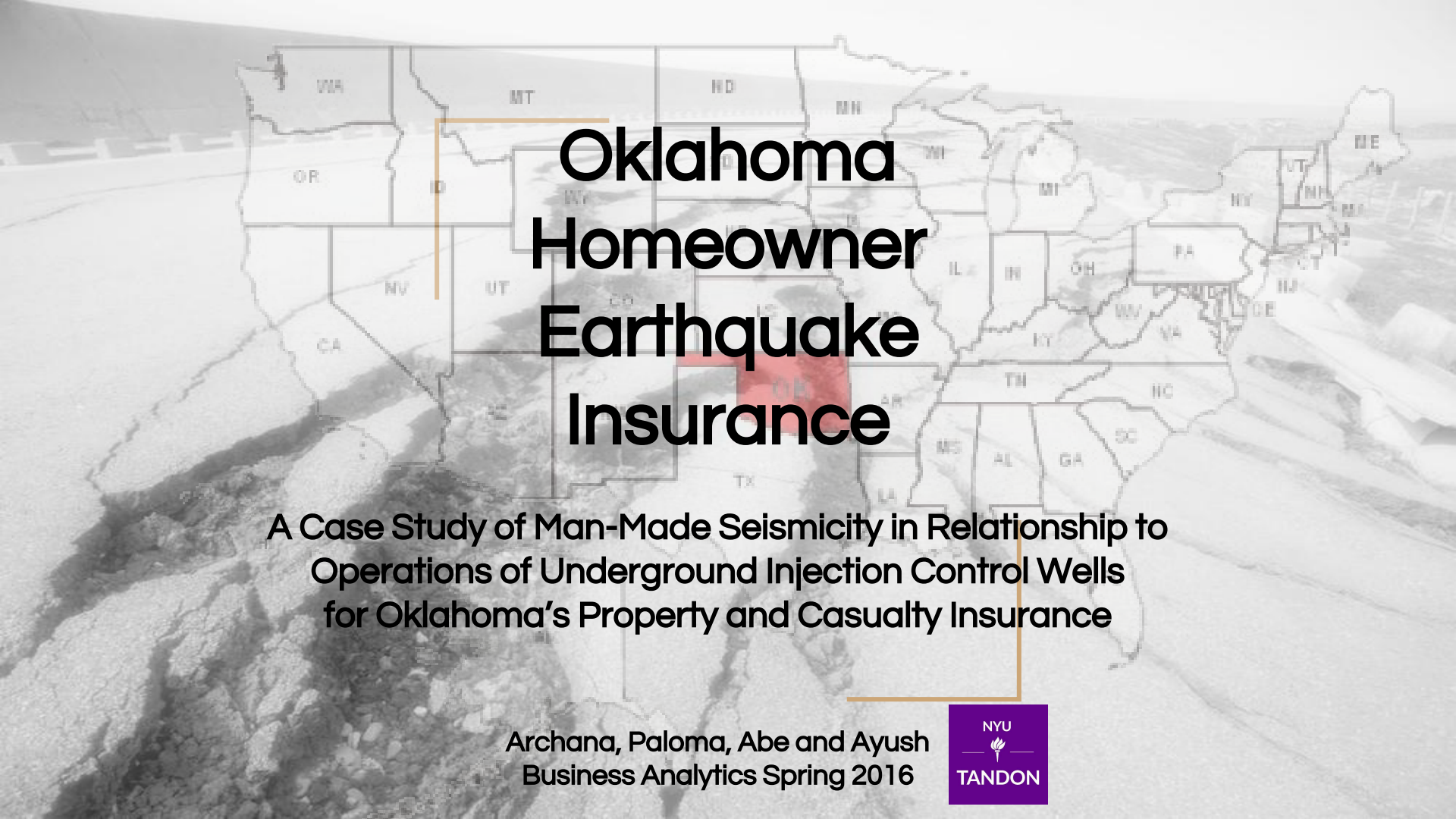


Oklahoma Homeowner Earthquake Insurance

A Case Study of Man-Made Seismicity in Relationship to Operations of Underground Injection Control Wells for Oklahoma's Property and Casualty Insurance

Archana, Paloma, Abe and Ayush
Business Analytics Spring 2016

NYU TANDON

Agenda

1. Objective
2. Problem statement
3. User stories
4. Methodology
5. Data Analysis
6. Insurance Product
7. Q&A

Oklahoma Homeowner Insurance Claims are being Denied if Damage is not Catastrophic

DAWNE SULLIVAN, OK HOMEOWNER

"The house has to come down. The foundation has to be completely ruined.

Something catastrophic has to happen for the insurance company to pay..."

What Does “Catastrophic” Mean?

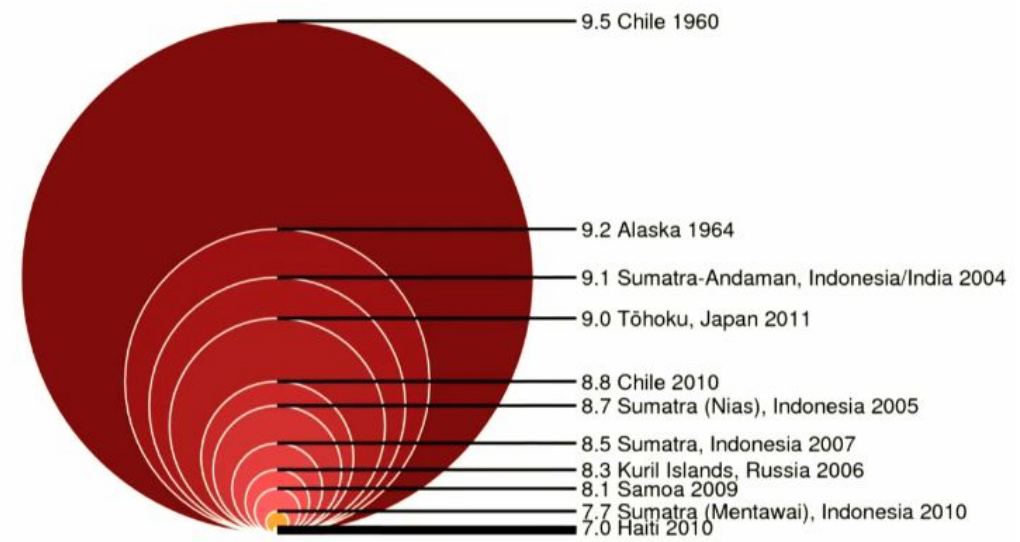
Magnitude 4 earthquakes (M4) or less can be felt, but M5.4 and stronger are destructive.

Each one-point increase in magnitude is 33x more powerful.

i.e. 2-point increase = 1000x.

M7.8 earthquake hit Ecuador’s Pacific coast on 16 April. Death toll passed 650, leaving 12,500 injured and 7,000 buildings destroyed (Al Jazeera, 04/24/16).

Comparison of Recent and Historic Earthquakes by Energy Release

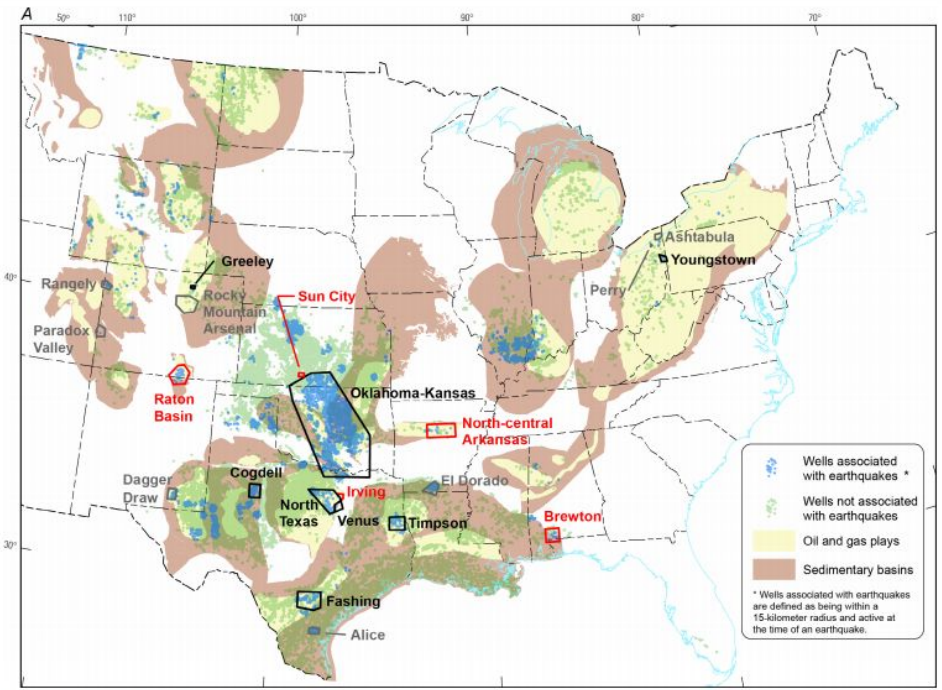


Most Oklahomans are Vulnerable to Earthquakes

- **15%** of Oklahomans have earthquake insurance, outpacing California **(10%)**
- Most state policies contain an exclusion for **"man-made" damage.**
- Policies carry high deductible **(5% to 10%)** and are designed for **catastrophic** damage.
- **92%** for insurance claims were denied in 2014

Induced Seismicity is Increasing in the Region

- According to USGS study*: “... a **remarkable** increase in the rate of magnitude 3+ earthquakes in Oklahoma
- It remains **unclear** how earthquakes are related to either changes in extraction methodologies or the rate of oil and gas production.”



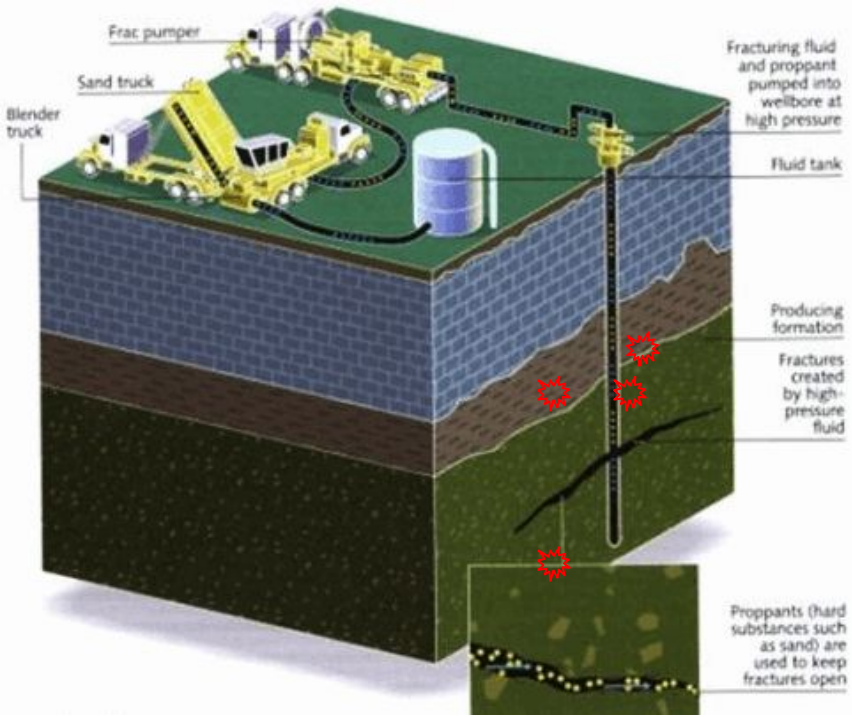
No Solid Proof that Oil Production is the Cause

CHAD WARMINGTON, OKLAHOMA
OIL AND GAS ASSOCIATION

"There are a lot of things that we can't explain. So what that leads us to believe is there's just a lot more science that we need to get to."

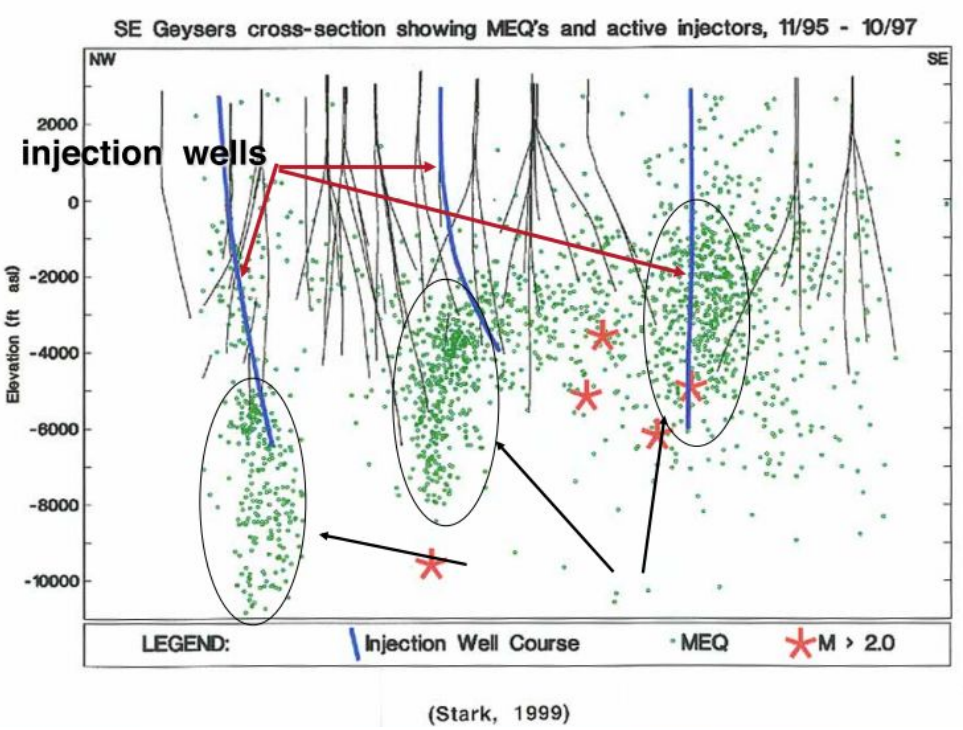
Man-made earthquakes are routine and well-understood

- Hydraulic fracturing oil and gas extraction process induces seismicity called “micro-earthquakes” of around magnitude 2 within 6 km in the earth's crust
- Oil and gas producers reinject waste water by-product deep underground which causes seismicity similar to that under water dams

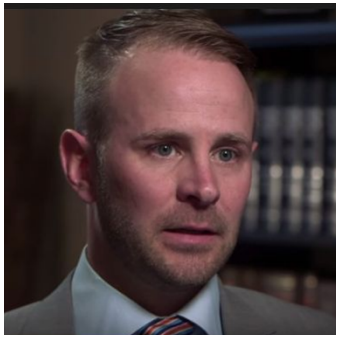


Underground Injection Triggers Natural Earthquakes

- Tectonic seismicity can be triggered by the cumulative effect of human activities overtime
- Increased pore pressure on critically stressed fault surfaces triggers seismicity
- Water reduces friction between faults releases energy and causes the earth to shake



No one Claims Responsibility and Homeowners are Dissatisfied with Current Insurance Offerings



CORY WILLIAMS, OKLAHOMA STATE REPRESENTATIVE

"Yes, you are inducing seismicity. Yes, you are growing to a bigger and bigger seismic activity. And yes, you need to stop."

"Homeowners' biggest frustration is whether they're going to get coverage under certain man-made exclusions in their policy."

BUDDY COMBS, OKLAHOMA INSURANCE COMMISSION

Insurors Not Respondings effectively to Homeowner Needs Despite Regulation

DEFINITION UNTIL OCTOBER 2015
Historic Exclusion of "Man-Made" Damage*

(a) "natural faulting of land masses" or

(b) "convulsion of the earth's surface caused by natural seismic forces" or

(c) "displacement within the earth's crust through release of strain associated with 'tectonic processes'."

Excluded loss due, in whole or part, to any "man-made" cause such as construction, mining, oil and gas exploration and production.

CLARIFICATION BY OKLAHOMA INSURANCE COMMISSIONER
Earthquakes Resulting from Oil and Gas Activities *

Subject to all policy provisions, the coverage provided by this policy (IS) or (IS NOT) intended to cover earthquake damage resulting from:

a. extracting oil or gas from below the earth's surface by any process, including but not limited to hydraulic fracturing or drilling; or

b. injecting or inserting any substance, including but not limited to, water and wastewater, below the earth's surface for any purpose; or

c. storage of any substance, including but not limited to, water and wastewater below the earth's surface for any purpose;

Can an Affordable Insurance Product be Created To Give Oklahoma Homeowners Peace of Mind against Man-Made Earthquakes and is Profitable to Insurance Providers at the same time?

Our goal is to explore available data to determine if such an insurance product is possible and viable.

What are the Relevant Conditions?

1. Are Earthquakes Becoming
   - More frequent
   - More powerful?
   - Concentrated around UIC Wells?
   - Deeper than before?
   - Potentially more Damaging than before?

Risk Assessment

2. Will enough Homeowners buy Insurance against damage from man-made activity to make the insured pool viable?
3. Will this insurance product be profitable?
4. Will it displace other insurance products we currently sell?

Profitability Assessment

Methodology

1. Data selection
2. Data preparation
3. Taxonomy and Definition of attributes
4. Data exploration
5. Approaches and Experimentation with tools
6. Descriptive analytics
7. Assess Risk Parameters for product recommendation
8. Product Recommendation

DATA

Data Selection

Database	Content	Source
One-year seismic hazard forecast for the Central and Eastern United States	Induced and natural earthquakes occurrence	U.S. Geological Survey (USGS)
Earthquakes dataset from 1977 to 2015	Earthquake data including date and time, location coordinates, magnitude and depth	Advanced National Seismic System (ANSS)/NEICPDE
Oklahoma Underground Injection Controll Wells (UIC) monthly reports from 1987 to 2014	Underground injection well data, including API number, monthly injection volume, and well location and attributes.	Oklahoma Corporation Commission
Oklahoma homeowner insurance claim data for earthquake-related events	Number of claims submitted, approved or denied.	Various sources

Datasets and Tools

Injection Wells [1987-2014]

.Well API Number: [state][county][well_id]
.Latitude
.Longitude
.Type [INJ, EOR, SWD,CWD]
.Depth
.Pressure
.Monthly Volume pumped

Earthquakes

[1971-2016]
.Earthquake ID
.Event Timestamp
.Depth
.Magnitude
.Longitude
.Latitude

Derived Datasets

.Detailed well lifetime profile record
.Cumulative injected fluid volumes
.Distance bet well & earthquake
.Distance between wells
.Clusters of related earthquakes and wells over time

Project Tools

R Studio
Tableau
Excel
MySQL
Google Fusion
Google Maps
Live Maps
AquaData

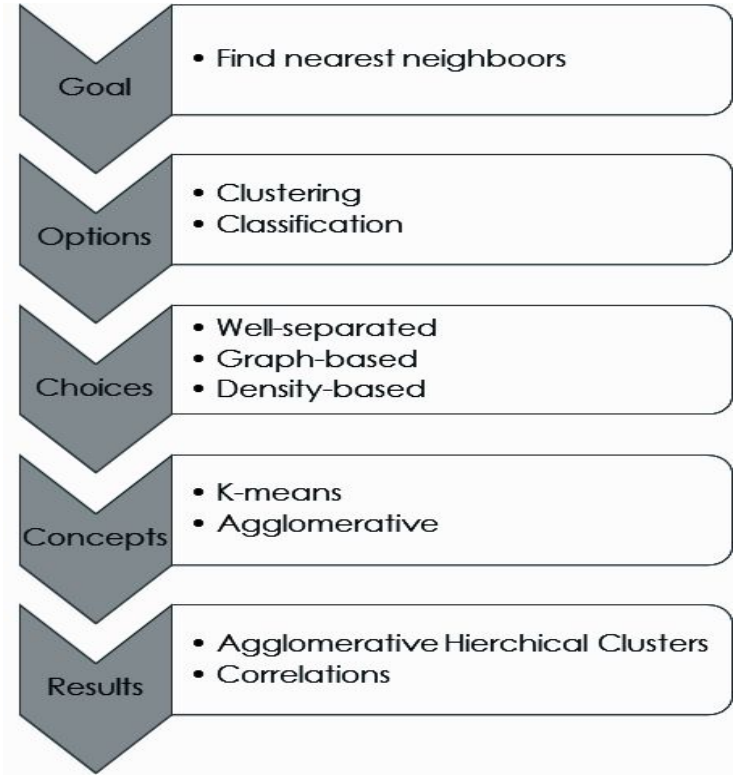
Dataset Size

17,000 wells
1,591,977 monthly volume reports
20,513 earthquakes
77 Oklahoma counties

Data Preparation and Exploration

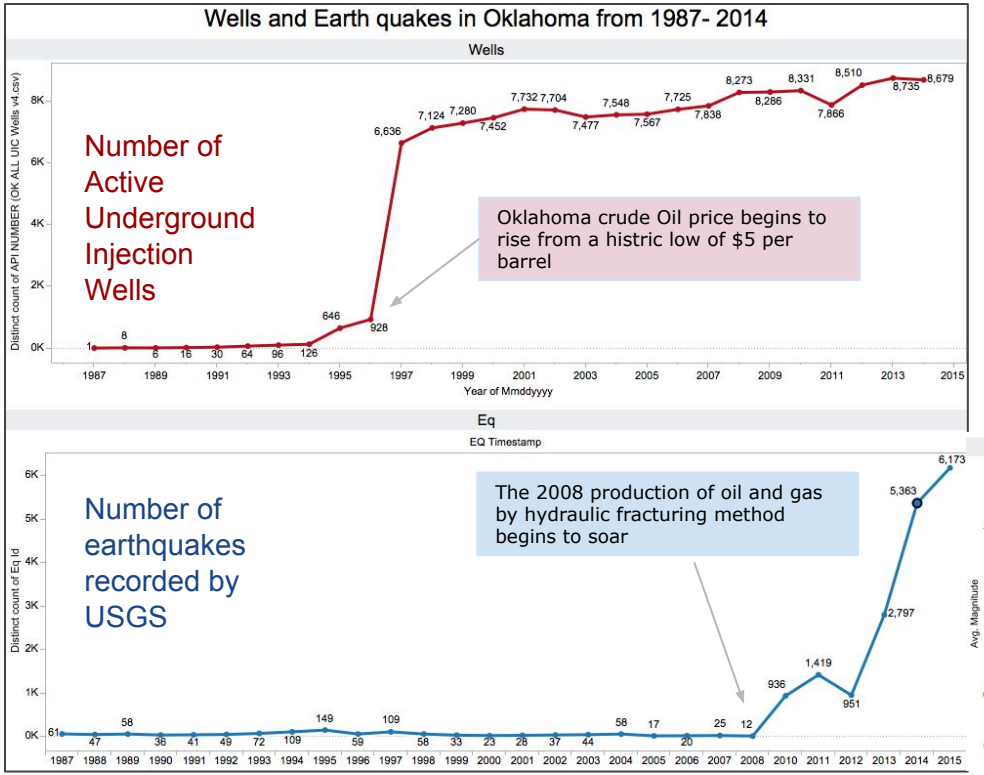
Goal: Allocate earthquakes to wells

1. Use only relevant data
2. Create useful datasets
3. Eliminate invalid values
4. Correct misaligned values
5. Convert to standard units of measurement
6. Deduplicate and correct recordsets
7. Spatial positioning
8. Distance Matrix
9. Determine optimal number of clusters for K-means cluster analysis on depth, location of wells and earthquakes
10. Visualization




DATA
INSIGHTS

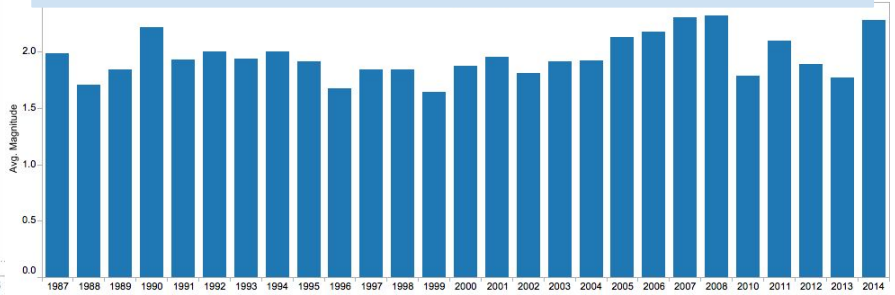
Oklahoma Earthquakes and Wells



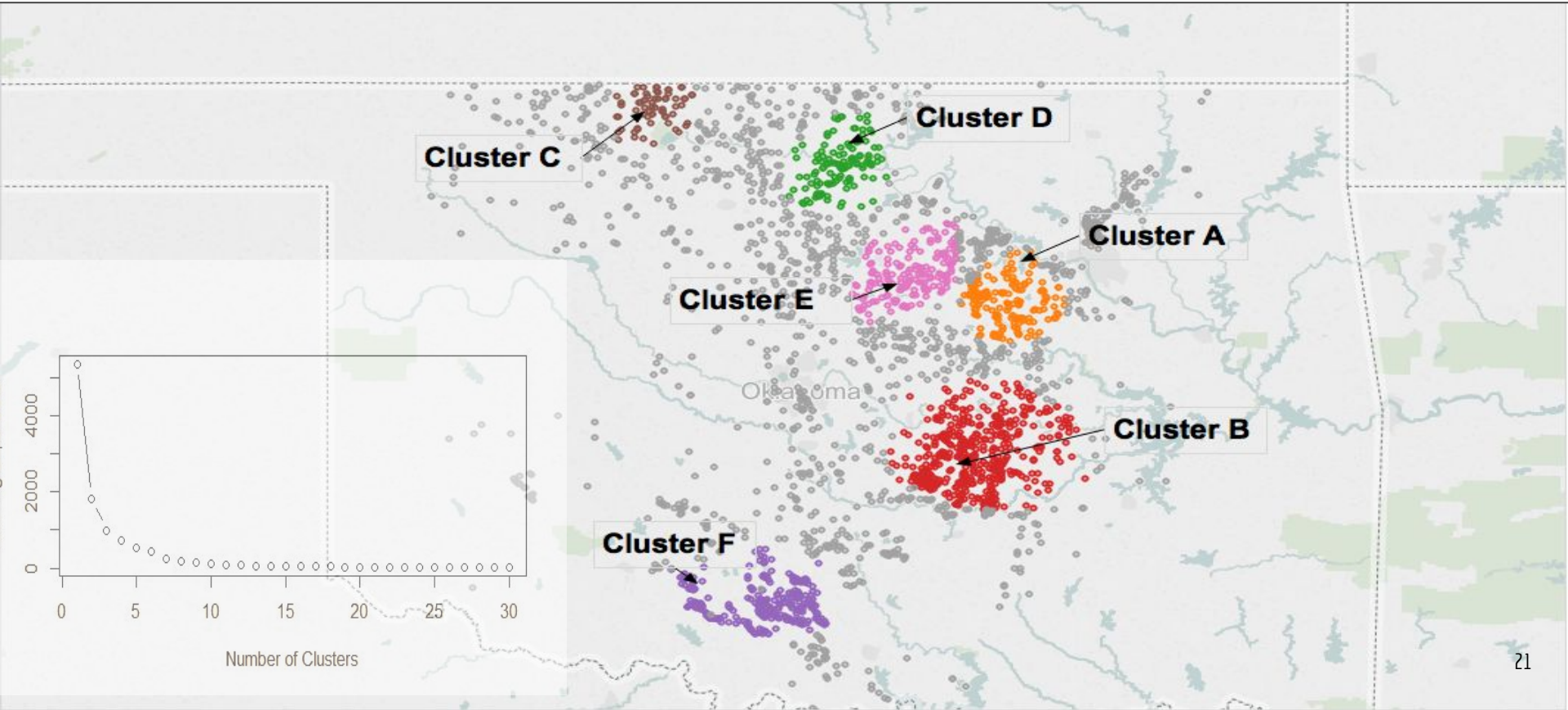
The number of earthquakes recorded per year is on the rise as expected due to sharp increase of oil extraction by the hydraulic fracturing method.

The magnitude of recorded earthquakes did not increase as the number of wells increased. The observed range is 1 - 3.5 on the Richter scale.

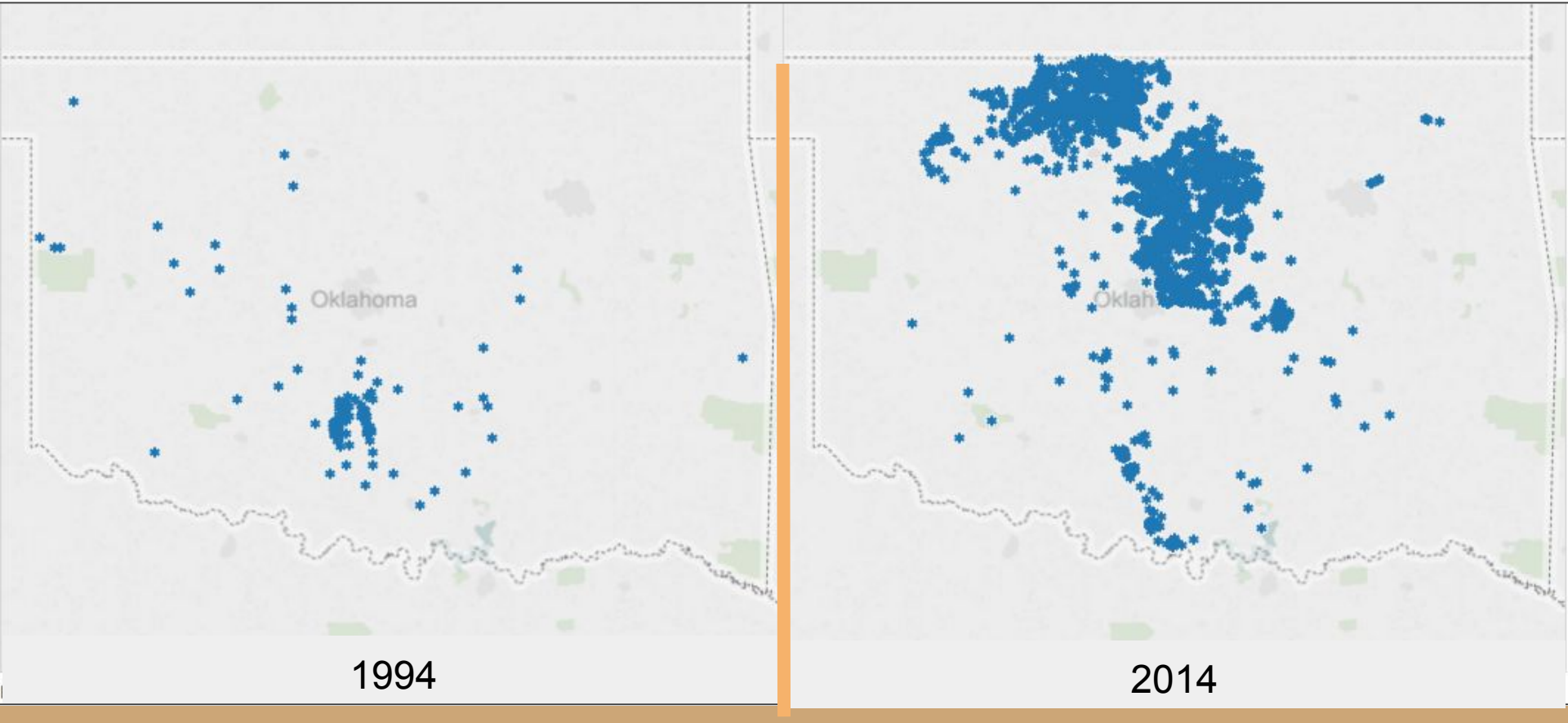
Earthquake magnitudes recorded in the remain in the 1 - 3.5 range
M < 2.5 are sensed only by seismograph
M 2.5 - 5.4 are felt but cause minor damage



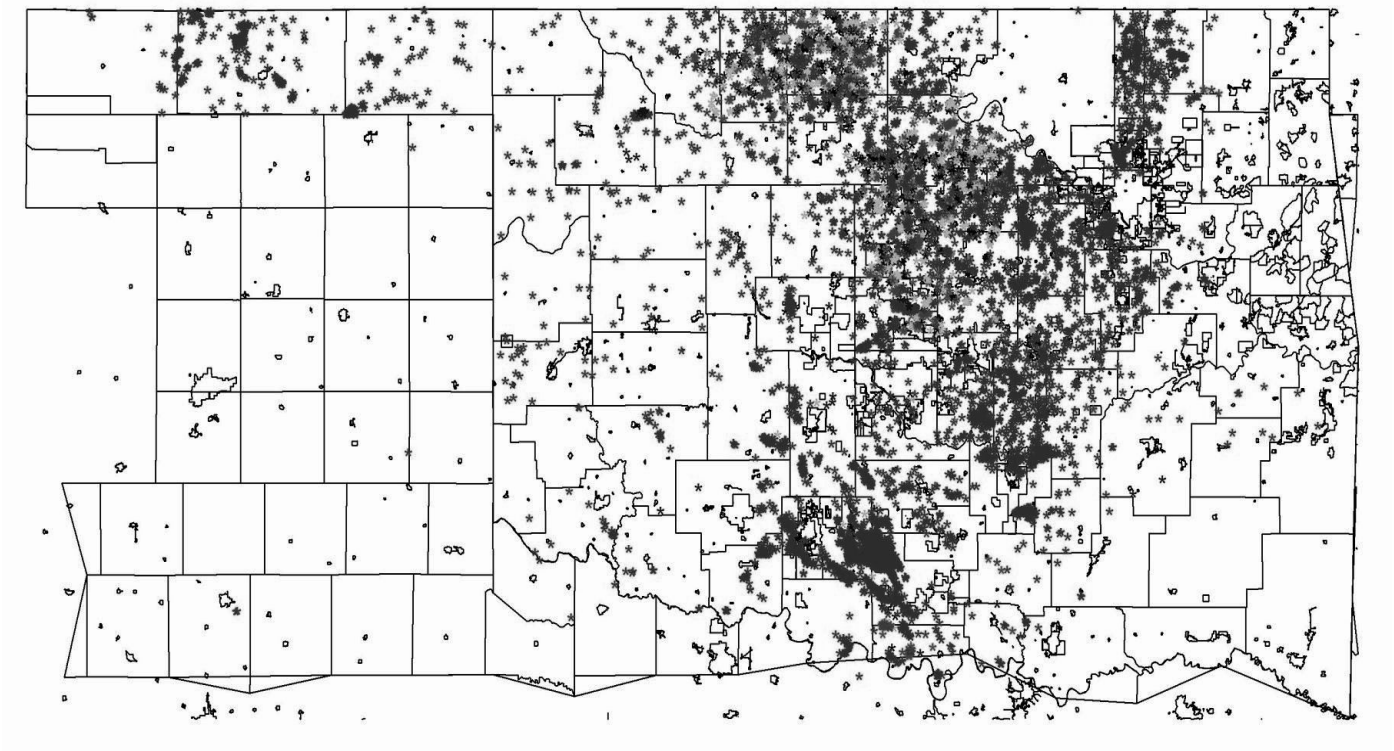
M2-3.5 Earthquakes within 1 mile of wells



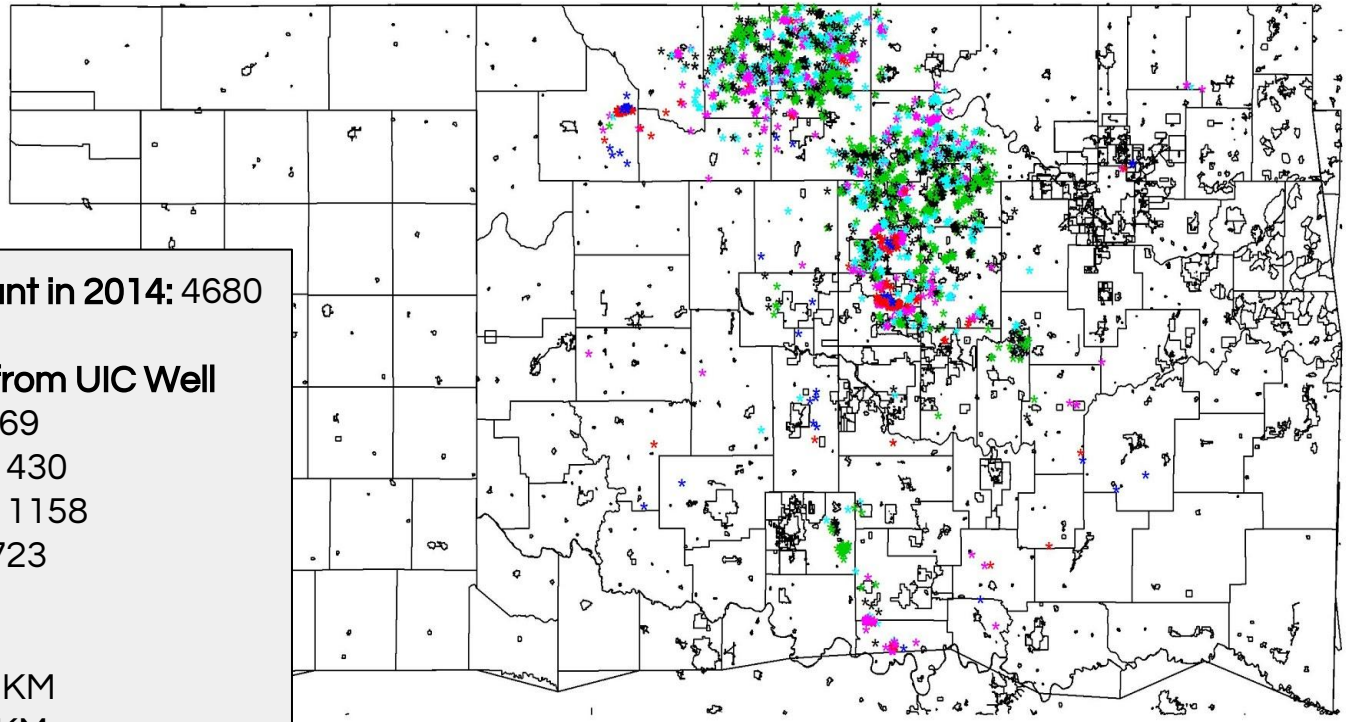
Earthquake Locations: 1994 vs 2014



Earthquake Locations: 1994 vs 2014



What Distance from Wells are Earthquakes Occurring?



Total Earthquakes count in 2014: 4680

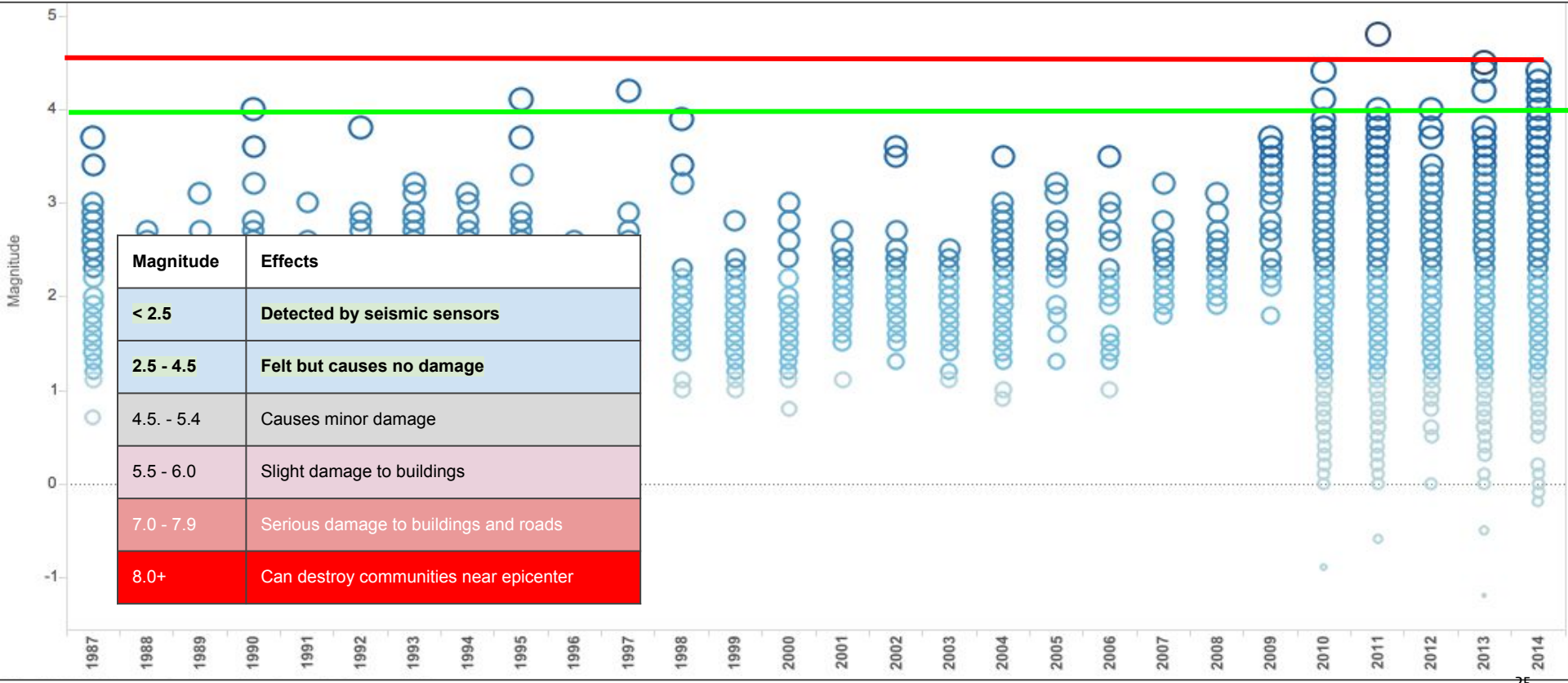
Earthquake Distance from UIC Well

Green: < 2 Km : 1369
Black: < 3.5 Km : 1430
Light blue: < 5.35 Km : 1158
Pink: < 7.8 Km : 723

Distance DIstribution

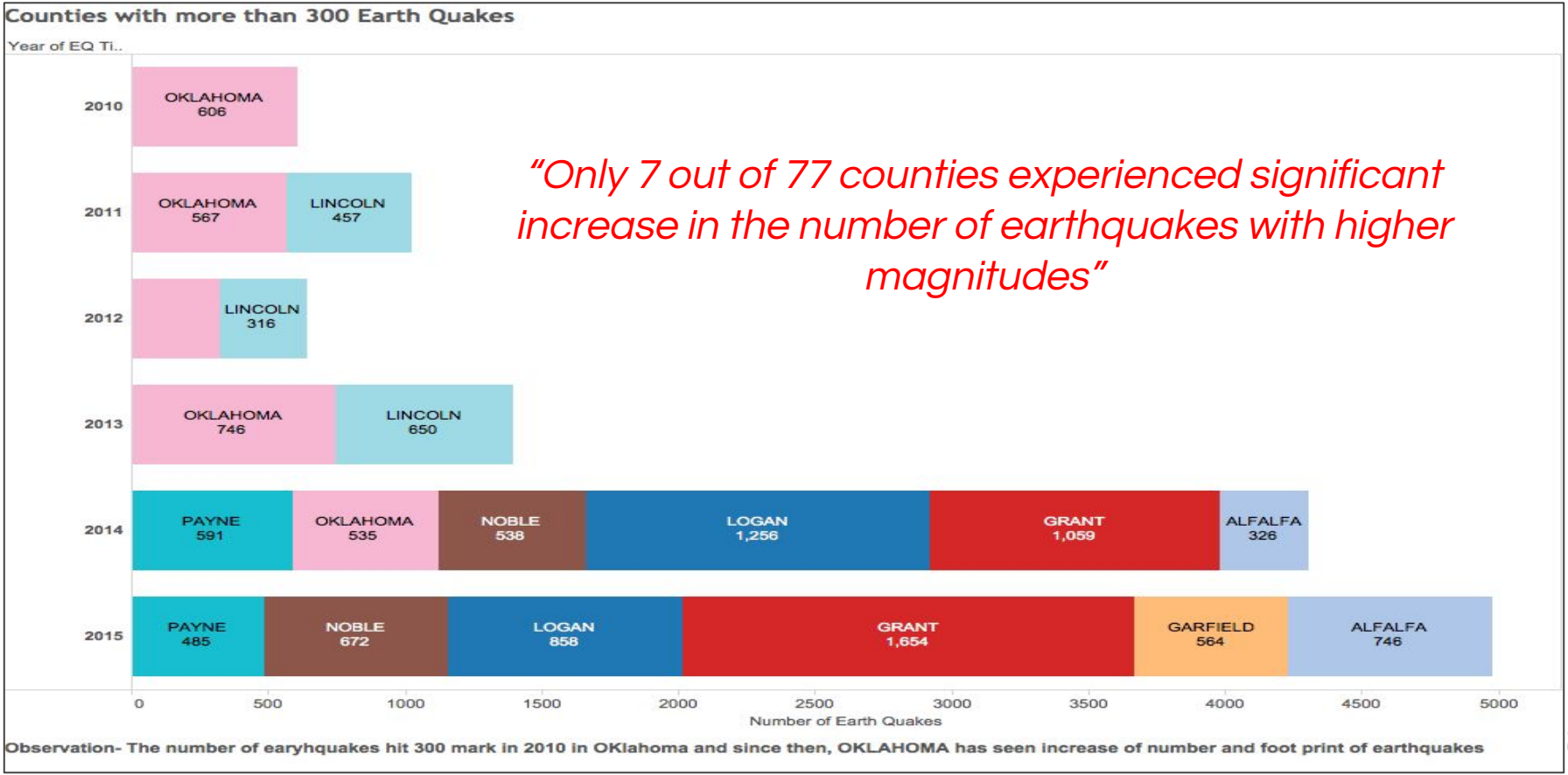
87.4% < 7.8 KM
99.9% < 15 KM

Earthquake Magnitude Trend



Magnitude	Effects
< 2.5	Detected by seismic sensors
2.5 - 4.5	Felt but causes no damage
4.5. - 5.4	Causes minor damage
5.5 - 6.0	Slight damage to buildings
7.0 - 7.9	Serious damage to buildings and roads
8.0+	Can destroy communities near epicenter

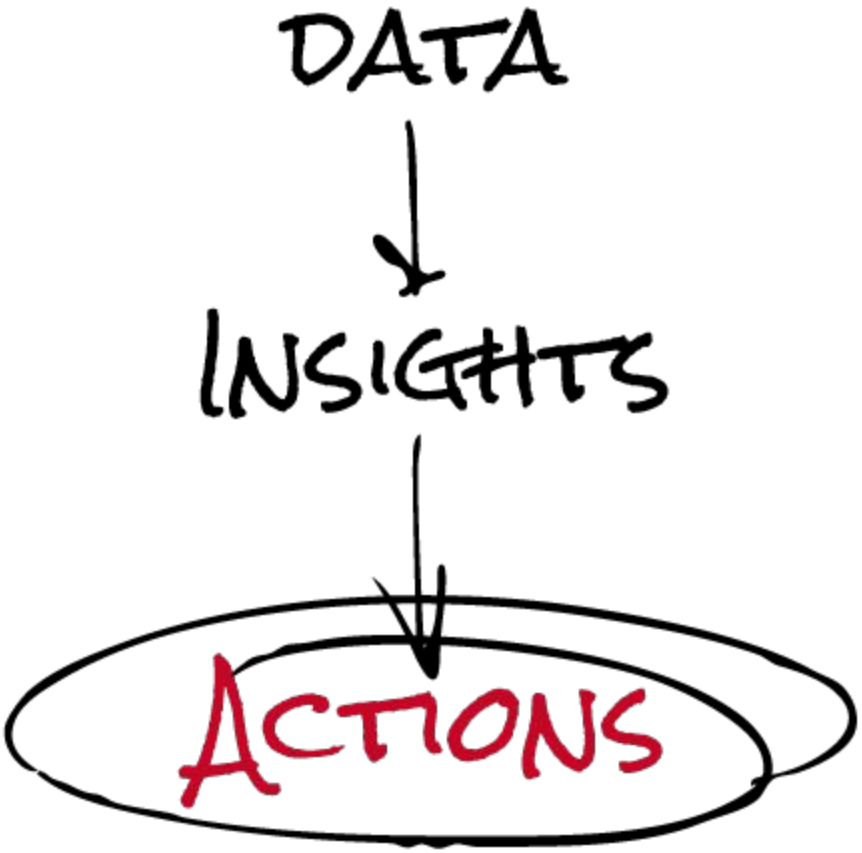
Counties Most Affected by Seismic Activity



"Only 7 out of 77 counties experienced significant increase in the number of earthquakes with higher magnitudes"

Claim Statistics for 2014

- Only 100 earthquake insurance claims were filed in 2014 for damage linked to seismic activity.
- Only 8 of the claims were approved.
- Numerous claims of felt seismicity, however, points to a public and media dissatisfied with the seemingly arbitrary science that insurance companies use to distinguish man-made from naturally occurring.
- Insurance companies cannot insure for zero-risk; they must price the risk according to likelihood of events


DATA
INSIGHTS
ACTIONS

Analysis Summary

1. Are Earthquakes Becoming
   - More frequent? ✔
   - More powerful? X
   - Concentrated around UIC Wells? ✔
   - Deeper than before? X
   - **Potentially more Damaging than before?** X
   -

2. Will enough Homeowners buy Insurance against damage from man-made activity to make the insured pool viable?

3. Will this insurance product be profitable?

4. Will it displace other insurance products we currently sell?

Risk Assessment is favorable

Profitability Assessment is favorable

New Earthquake Product for All Types of Seismicity

-Price according to risk and number of participants of the program

-Providers should price earthquake insurance to entice a large number of homeowners to subscribe

-Price policy according to location, type of construction, value of home and deductible.

-Product is sold over and above homeowners policy thus won't cannibalize existing products

Average OK House Price	$150,000
Average Household Income	$43,000
Deductible Rates	2%, 5% and 10% of property value
Earthquake Premium	$0.06 to $0.30 per $1,000 of dwelling
Cost considerations	Location, building age, construction materials, deductible
Coverage	Dwelling only as addition insurance to primary policy

Q&A

References

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http://www2.seismosoc.org/FMPro?-db=Abstract_Submission_12&-sortfield=PresDay&-sortorder=ascending&-sortfield=Special+Session+Name+Calc&-sortorder=ascending&-sortfield=PresTimeSort&-sortorder=ascending&-op=gt&PresStatus=0&-lop=and&-token.1=ShowSession&-token.2=ShowHeading&-recid=224&-format=%2Fmeetings%2F2012%2Fabstracts%2Fsessionabstractdetail.html&-lay=MtgList&-find

https://slack-files.com/files-pri-safe/T0QLAS0US-F0SE8G5RP/potential_injection-induced_seismicity_associated_with_oil___gas_development.pdf?c=1462365834-8be7e43736ed95b319d44379520f7458fa0b2088

http://www.pbs.org/newshour/bb/spike-in-earthquakes-rattles-oklahoma-oil-gas-industry/

https://www-users.cs.umn.edu/~kumar/dmbook/ch8.pdf

Appendix 1: Injection Wells Data Available

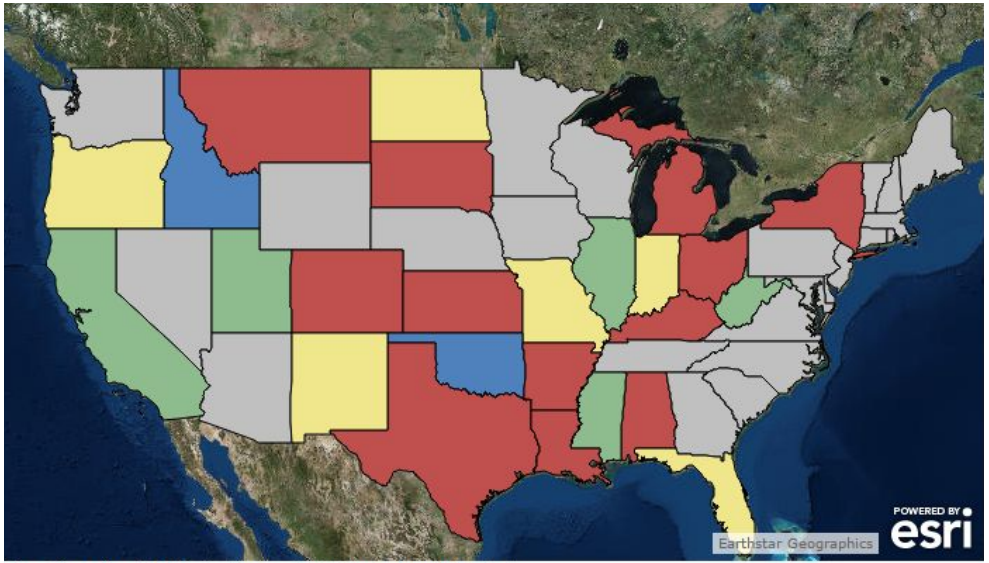
Oklahoma has various online oil and gas databases. Links include: "Archived Oil & Gas Database", "New Well Browse Database", "Oil and Gas Data Mining".

Texas results cannot be downloaded and do not include location coordinates.

Arkansas results are presented at Google Earth map and no excel spreadsheet is available for download..

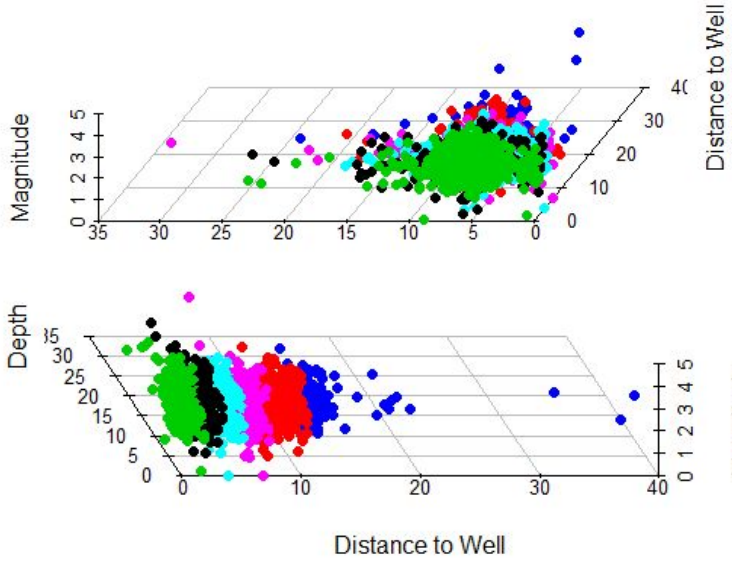
Tennessee has no data available.

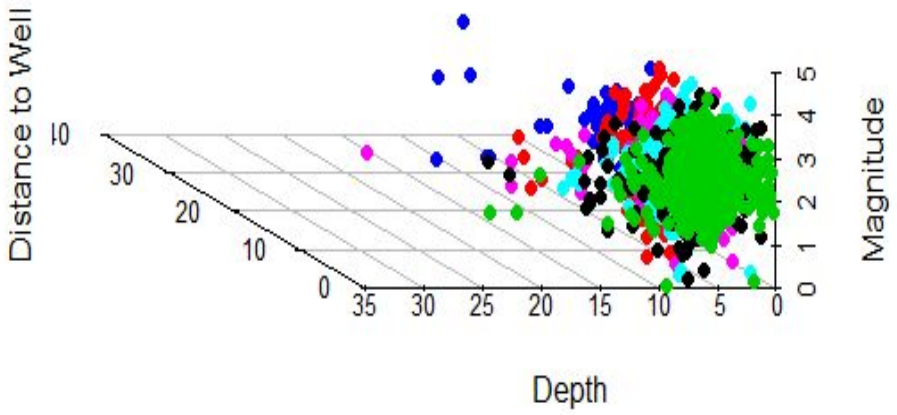
California has related data, but not specific on injection wells.



Blue: Downloadable injection well database found for state
Red: Downloadable oil and gas well database found for state
Green: Other downloadable data found for state
Yellow: Only online resources found (ie online maps, online permit searches, etc..)
Grey: Data quality is poor or no data was found

Appendix 2: Earthquake Clusters by Magnitude and Depth and distance from a Well





Our analysis shows that more destructive earthquakes occurred **below 6 km and >M4**

Appendix 3: Distance Calculation and Clustering

```
84  #Requires package rgeos for gdistance
85  require(rgeos)
86  distance.matrix <- matrix(0,nrow(earthquakes),7,dimnames=
87      list(c(),c("EQ_ID","Lat","Long","Mag","EQ_Timestamp","Depth","DistWell")))
88
89  for(i in 1:nrow(earthquakesUTM)){
90    sub <- earthquakesUTM[i,]
91    DistWell <- gDistance(sub,wellsUTM)
92    distance.matrix[i,] <- matrix(c(sub$EQ_ID,sub@coords,sub$MAGNITUDE,sub$EQ_Timestamp,sub$DEPTH,gDistance(sub,wellsUTM)),ncol=7)
93  }
94
95  distanceMatrix = as.data.frame(distance.matrix)
```

```
101  #Finding optimum number of clusters
102  mydata <-  scale(distanceMatrix[,7])
103  wss <- (nrow(mydata)-1)*sum(apply(mydata,2,var))
104  for (i in 2:30) wss[i] <- sum(kmeans(mydata,centers=i)$withinss)
105  plot(1:30, wss, type="b", xlab="Number of Clusters",
106       ylab="Within groups SSE")
107
108  ##The graph indicates the relationship of SSE and number of clusters
109  #After 7 clusters, the SSE value doesnt decrease significantly so we choose to make 7 clusters
110
111  help("kmeans")
112  clust <- kmeans(mydata,7)
```