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OKLAHOMA GEOLOGICAL SURVEY

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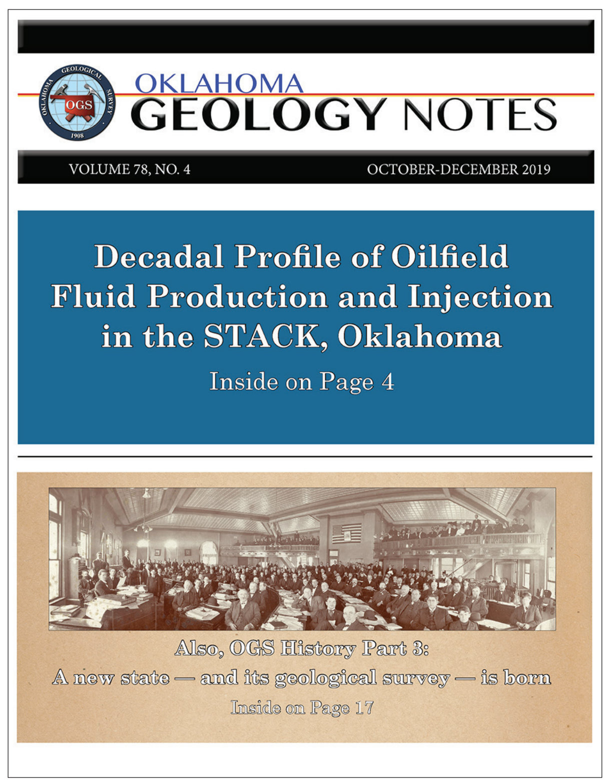
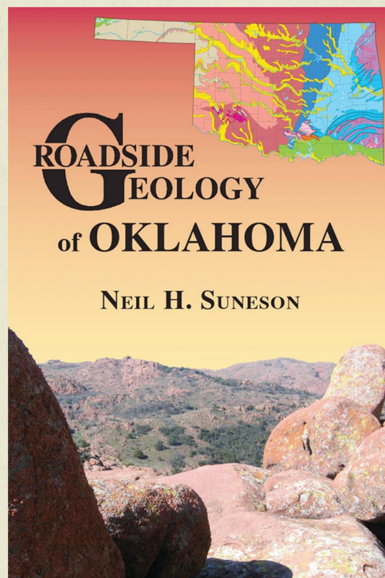


Photo on cover is of the participants of the Oklahoma Constitutional Convention in November of 1906. Cover design by Ted Satterfield.

Dear readers,

At the time of this writing there are no new updates about the search for the new OGS director, so, instead, I'll take a minute to promote a book that has been in the works for many years. Retired OGS geologist Neil Suneson's book "Roadside Geology of Oklahoma" has officially been published by Mountain Press. This is the first book about Oklahoma in the long-running Roadside Geology series. It's an exceptionally good book that is interesting to scientists, but, also, manages to remain accessible to those with limited scientific knowledge. It can be purchased at the OGS Publication Sales Office or wherever books are sold. I'll be writing an article in the next issue of the Notes that delves much deeper into the topic of this book, but for now, we highly recommend you check it out.



Kind Regards,

Ted Satterfield
OGS Editor

Decadal Profile of Oilfield Fluid Production and Injection in the STACK, Oklahoma

By

Dr. Kyle Murray

Hydrogeologist, Oklahoma Geological Survey

ABSTRACT

Unconventional oil and gas development has led to historically high rates of oil and gas production in many U.S. plays. Associated hydraulic fracturing requires more water-based fluids on demand during drilling and completion, and completed wells may co-produce much large volumes of (brine) water. Water management in the oil and gas industry has become increasingly important as an outgrowth of the more dynamic water supply and demand. Dramatic increases in produced water volumes generally translate to dramatic increases in saltwater disposal volumes. So, there are numerous stresses from fluid production and fluid injection that have been linked to seismic activity in unconventional plays. The last decade of activity in Oklahoma epitomizes the complexities between well completion, stimulation, oil and gas production, co-produced water, saltwater management, and induced seismicity. Oklahoma's Sooner Trend Anadarko Canadian Kingfisher (STACK) region overlaps the area of interest (AOI) where the Oklahoma Corporation Commission (OCC) has worked with operators to mitigate seismicity by limiting saltwater disposal (SWD) or adjusting hydraulic fracturing protocols. The objectives of this paper are to report available production and injection data and perform a preliminary analysis of correlations to seismicity.

Results indicate that oil and gas production increased from wells in the STACK from 2009–2018 timeframe with about 200,000 barrels of oil per day (BOPD) and about 500,000 barrels of oil equivalent gas per day (BOEPD) during 2018. SWD rates increased too, with about 640,000 barrels of water per day (BWPD) into the collective zones (i.e., Permian to Arbuckle and other) in 2018. However, enhanced oil recovery injection (EORI) rates were steady and amounted to about 100,000 BWPD into the collective zones. These monthly-scale data were correlated to the rate of $M \geq 2.3$ earthquakes in the STACK using Pearson correlation coefficients and F-statistics. Numerous factors are correlated with seismicity with R-squared values being as high as 0.4670 for SWD into Permian. Mississippian oil production and gel frac injection were most strongly correlated and most significant based on F-statistics. Many of the human activities that correlate to seismicity are cross-corre-

lated, so additional analyses and modeling studies are required to understand the mechanisms that have the greatest effect on subsurface stresses.

1. INTRODUCTION

Despite predictions of reaching peak oil production a few decades ago, worldwide oil and gas reserve estimates and production rates continue to increase, especially in the United States. Regions or plays that were previously exhausted or unreachable with conventional technology are now being exploited or redeveloped. Accessing and producing unconventional oil and gas resources involves a new generation of management decisions that must counterbalance technical knowhow versus economical and business sense. For example, production from unconventional wells may result in water cuts and produced water volumes that are orders of magnitude higher than from the same region's conventional wells in prior eras of production. Water use on the frontend and produced water management on the backend of exploration and production (E&P) operations requires more complex cost-benefit analyses. For an industry that has dynamic water demands, matters are further complicated in drought prone regions where water supply is limited or highly variable from year to year. Seismicity that may be associated with Class II underground injection control (UIC) wells has also become intertwined with produced water (i.e., brine) management. In particular, permitting and injection of wastewater into saltwater disposal (SWD) wells is factored into decision-making and management of flowback, produced water, and waste products from E&P operations. Thus, since about 2010, water cost units and water resources management have emerged as important issues in the oil and gas industry.

1.1 OKLAHOMA PATTERNS

Oil and gas have been produced from reservoirs in Oklahoma since the early 20th Century. Historical oil production from Oklahoma wells peaked at 761,027 barrels of oil per day (BOPD) in 1927. Peak production during the 1920s was followed by steady declines to a near century low of 167,841 BOPD in 2005, the lowest rate since 140,511 BOPD in 1912. Unconventional development began in Oklahoma in the early 2000s with the advent of horizontally drilled and hydraulically fractured wells in the Arkoma Basin's Woodford Shale. Unconventional well drilling and completion techniques quickly spread to the rest of the state and allowed for new production or redevelopment from a variety of oil and gas producing zones. This unconventional revolution has resulted in oil production of up to 549,822 BOPD in 2018, which is the highest rate for Oklahoma oil production since 1971. Modern gas production in Oklahoma reached an all-time historical high of 1.35 million barrels of oil equivalent per day (BOEPD) in 2018. EIA accounts of Oklahoma oil and gas production in 2019 indicate that monthly highs of 613,000 BOPD and 1.46 million BOEPD were reached in April 2019. These are both monthly highs in comparison to EIA accounts of monthly production rates that date back to January 1997.

Along with increased oil and gas production has been a concomitant increase of produced water volumes that are mostly documented in Operator's SWD reports submitted to the Oklahoma Corporation Commission (OCC). Statewide SWD rates peaked at 4.57 million barrels of water per day (BWPD) in September 2014. A substantial increase in seismicity, above background rates, started in 2009 and peaked at 3.5 EQs (≥M3.0) per day in June 2015. Seismicity and a reduced oil price in mid-2014 have left indelible marks on E&P activity in Oklahoma. The area of interest (AOI) defined by the OCC in central and north-central Oklahoma encompassed the majority of seismic activity that occurred in Oklahoma and was the target area for mitigation efforts. Directives issued by the OCC over the 2015 to 2017 timeframe mainly aimed to reduce volumes or rates of SWD into the Arbuckle zone.

Research by the OGS suggested that substantial geological differences must be considered in the AOI and data must be compiled and interpreted at the sub-regional scale to account for past or predict future oil, gas, and water production patterns or to better mitigate seismic activity. So, in 2017 the OCC and OGS sub-divided the AOI into seven geological prov-

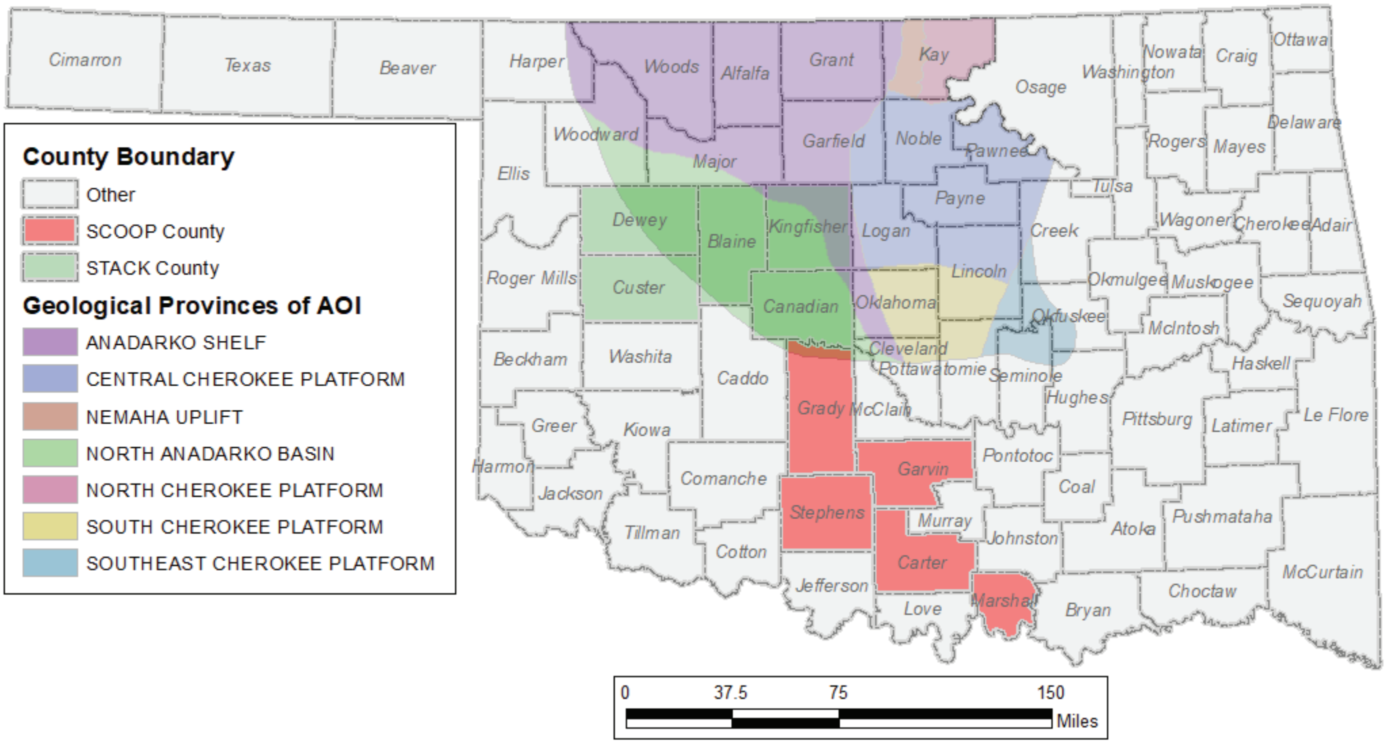


Figure 1 Map of Oklahoma showing the Geological Provinces within the AOI and highlighting the SCOOP and STACK Counties

inces based on substantial vertical displacement along a mapped fault (i.e., Nemaha fault zone), geological hinge lines coinciding with historic geological province boundaries (i.e., Anadarko Shelf vs. Anadarko Basin), or apparent demarcation lines between oil, gas, and water production or seismicity trends. The seven geological provinces include the Anadarko Shelf, Central Cherokee Platform, Nemaha Uplift, North Anadarko Basin, North Cherokee Platform, South Cherokee Platform, and Southeast Cherokee Platform (Figure 1). Unique characteristics of plays or regional geological systems must be evaluated to understand oil, gas, and water production trends and to efficiently manage water in the energy industry.

1.2 STACK CASE STUDY

Oil and gas production in the Sooner Trend Anadarko Canadian Kingfisher (STACK) including Blaine, Canadian, Custer, Dewey, and Kingfisher Counties commenced in 1950 or earlier. After the price drop in mid-2014, Oklahoma's E&P activity intensified in the STACK partly because the region boasts several economical and management advantages over plays (i.e., Mississippian Lime) in the heart of the AOI. One perceived advantage is that the ratios of water to oil (H_2O:oil) and water to gas (H_2O:gas) are relatively low in comparison to producing units developed from 2005 to 2014 in the Anadarko Shelf or Cherokee Platform provinces of the AOI. In addition, thicker Pennsylvanian age zones are separated from the basement by thousands of feet which may minimize the potential for injection-induced seismicity.

Trends for STACK fluid production and produced water management must be examined over the 2009 to 2018 timeframe to anticipate and plan for management of those resources into the future.

1.3 OBJECTIVES

The objectives of this STACK study are to quantify and report 1) monthly rates of fluid injection for hydraulic fracturing activities, 2) monthly rates of oil and gas production by zone, 3) monthly rates of brine or brackish water reinjection into UIC wells, 4) produced water quality for representative samples of produced water, and 5) monthly seismicity rate. In addition, basic statistical measures of correlation and

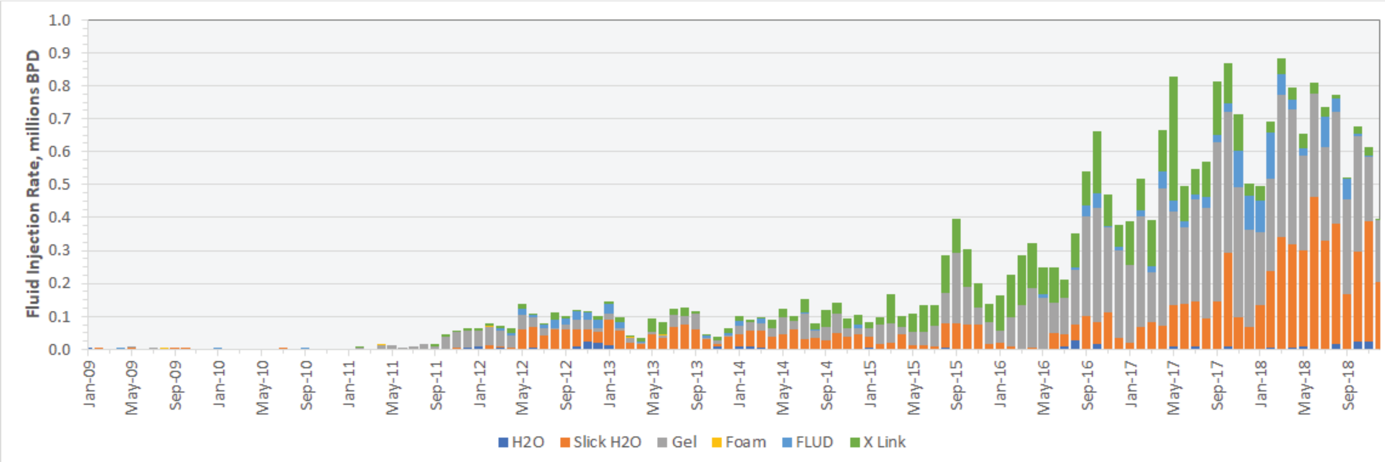


Figure 2 Monthly fluid injection rates for hydraulic fracturing activities in the STACK, 2009-2018

significance will be calculated for STACK monthly fluid injections and fluid productions versus seismicity.

2. METHODS

2.1 OIL AND GAS DATA

Production Header, Production Well, and Monthly Production tables were downloaded from a commercial database (IHS, 2019) for Blaine, Canadian, Custer, Dewey, and Kingfisher Counties. Records in the tables were joined in a relational database using the entity, universal well identifier (UWI), and API number attributes. The Producing Zone Name attribute in the Production Header table was compared to a lookup table for Formations versus Zones so that production could be allocated to one of the twelve zones defined by Murray (2015). In addition, Test and Test Treatment tables were downloaded from IHS and used to compile data for hydraulic fracturing, well stimulation, and initial potential or production tests.

2.2 UIC DATA

The UIC database previously built by Murray (2015) was appended and updated using well completion reports (Form 1002As) and annual fluid injection reports (Form 1012As) available at http://imaging.occeweb.com/imaging/OGWellRecords.aspx and http://imaging.occeweb.com/imaging/UIC1012_1075.aspx, respectively. Attributes were appended or updated from 1002A reports for each UIC well including latitude, longitude, ground surface elevation, injection depth, and formation(s) into which fluid is injected. Injection formation(s) were compared to a lookup table of Formations versus Zones so that injection zone could be allocated to one of the twelve zones defined by Murray (2015). Attributes for type of well (e.g., 2D or 2R), fluid (e.g., SW, BW, or CO2), and monthly volumes were obtained from 1012A forms and populated in the UIC database.

2.3 PRODUCED WATER QUALITY DATA

Analytical reports for produced water quality were compiled from OCC records related to UIC permit applications in the STACK region. These data were submitted to the OCC according to OAC 165:10-5-5 (OCC, 2016), which states in part 5D that UIC applications (Form 1015) shall be accompanied by "Qualitative and quantitative analysis of representative sample of water to be injected". The analysis shall include at a minimum chloride, sodium, and total dissolved solids (TDS). Permit applications were reviewed and produced water quality reports were compiled into a water quality database for Oklahoma (Murray, 2019-in progress). Chloride, sodium, and TDS concentrations were summarized for samples that were available in the STACK.

2.4 SEISMICITY DATA

The Oklahoma Earthquake Catalog was downloaded from the OGS web-page (http://www.

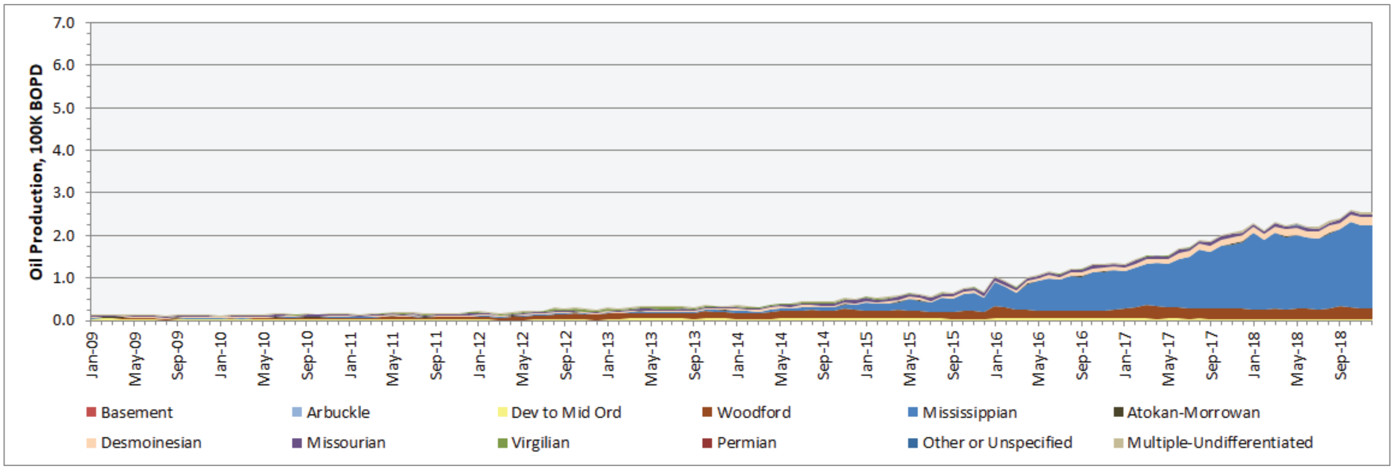


Figure 3 Monthly oil production rates by zones in the STACK, 2009-2018

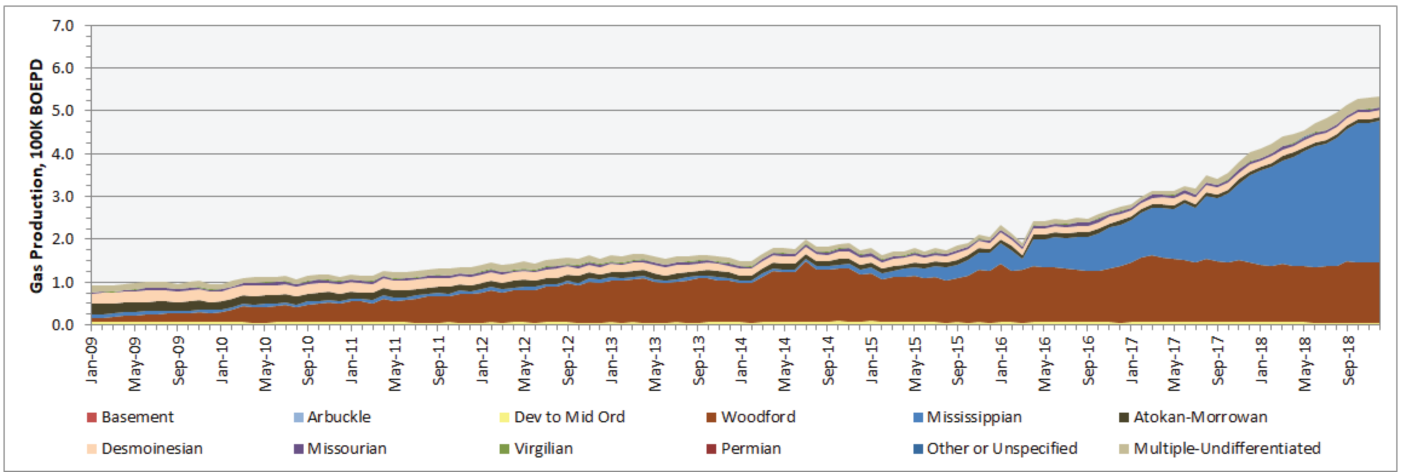


Figure 4 Monthly gas production rates by zones in the STACK, 2009-2018

ou.edu/ogs/research/earthquakes/catalogs). Number of earthquakes equal to or greater than magnitude 2.3, Oklahoma's magnitude of completeness for the seismic network, were tabulated on a monthly time scale from January 2009 to October 2019 for the STACK counties.

2.5 CORRELATION COEFFICIENTS FOR FLUID INJECTIONS OR PRODUCTIONS VERSUS SEISMICITY

Pearson correlation coefficients (R-squared) were computed for numerous independent variables (e.g., SWD into a specific zone or production from a specific zone) against a dependent variable (i.e., seismicity rate) using monthly records (i.e., 10 years or 120 consecutive months). Because there are possible time lags between activity (e.g., injection) and response (e.g., earthquake), the R-squared between independent and dependent variables were calculated for a forward time lag of up to 10 months. Because HF injections include six fluid types and oil, gas, and water injections and productions are organized by 12 zones (e.g., Permian…Mississippian…Basement), all with up to 10 month time lags, over 500 correlations were calculated. After determining the top five highest R-squared values for numerous factors/time lags versus seismicity rate, then the R-squared value and F-statistic were recomputed with a zero y-intercept. In other words, it is not possible to have a negative number of M≥2.3 earthquakes.

3. RESULTS

3.1 FLUID INJECTION FOR HYDRAULIC FRACTURING

Fluid injection rates for hydraulic fracturing increased from January 2009 until the end of 2017 and

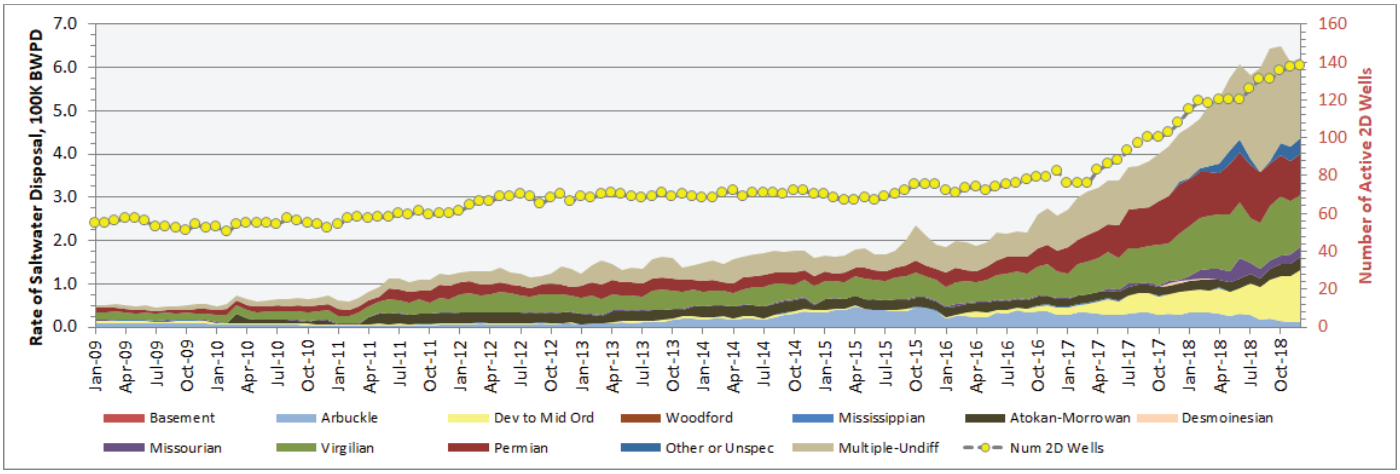


Figure 5 Monthly saltwater disposal (SWD or 2D) rates in the STACK, 2009-2018

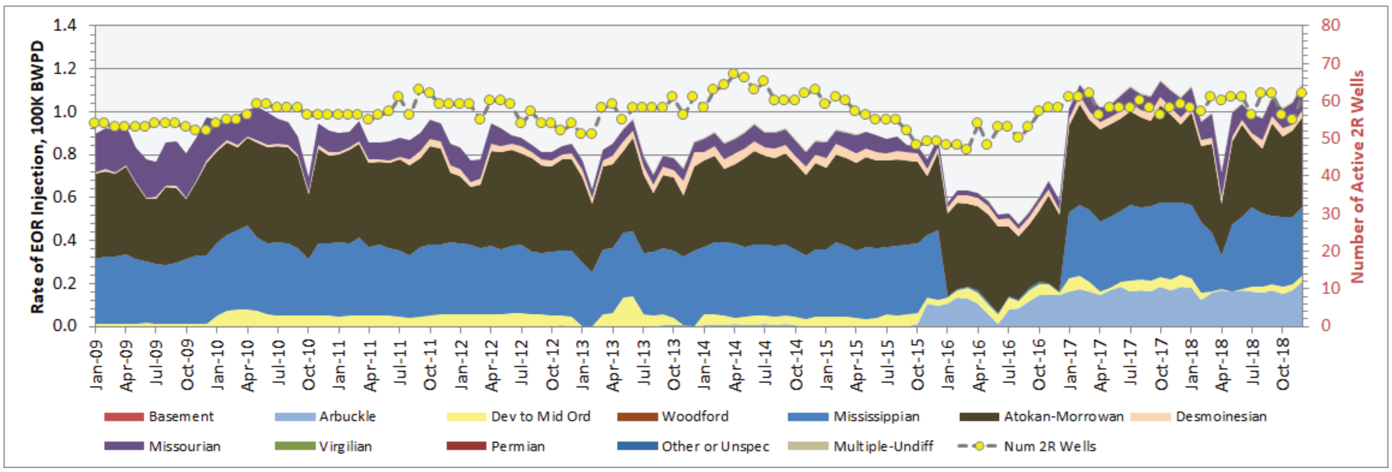


Figure 6 Monthly enhanced oil recovery injection (EORI or 2R) rates in the STACK, 2009-2018

into 2018, which is indicative of drilling and completion activity in the STACK (Figure 2). The fluid injection rate reached a maximum of nearly 900,000 BPD in March of 2018. Water (H_2O), slick H_2O, gel, foam, flud, and cross link (X Link) were reportedly used over the 10-year period of record, with slick H_2O and gel fracs accounting for a large majority of the injected fluid volumes in 2017 and 2018.

3.2 OIL AND GAS PRODUCTION

Oil production steadily increased from wells in the STACK over the 2009 to 2018 timeframe with sustained production of about 200,000 BOPD during 2018 (Figure 3). The majority of oil was produced from the Mississippian Zone with substantial production increases beginning in 2015.

Gas production steadily increased from wells in the STACK over the 2009 to 2018 timeframe with about 500,000 BOEPD during late 2018 (Figure 4). The majority of gas was produced from the Woodford Shale zone until the end of 2017, after which the Mississippian zone was the predominant gas producer in the STACK. The most commonly reported producing formations in the Mississippian zone were the Mississippian Lime, Mississippian Solid, Meramec, Osagian Series, Chester, and Sycamore.

3.3 UIC INJECTION

There was an increase in wastewater disposal into SWD (i.e., 2D) wells in the STACK from 2009 to 2018, to accommodate higher produced water volumes associated with increased oil and gas production. Collective SWD rates of about 640,000 BWPD were estimated for late 2018, with highest SWD rates into the Multiple-Undifferentiated, Permian, and Virgilian zones (Figure 5). There were about 140 SWD (i.e., 2D) wells actively injecting in December of 2018 for

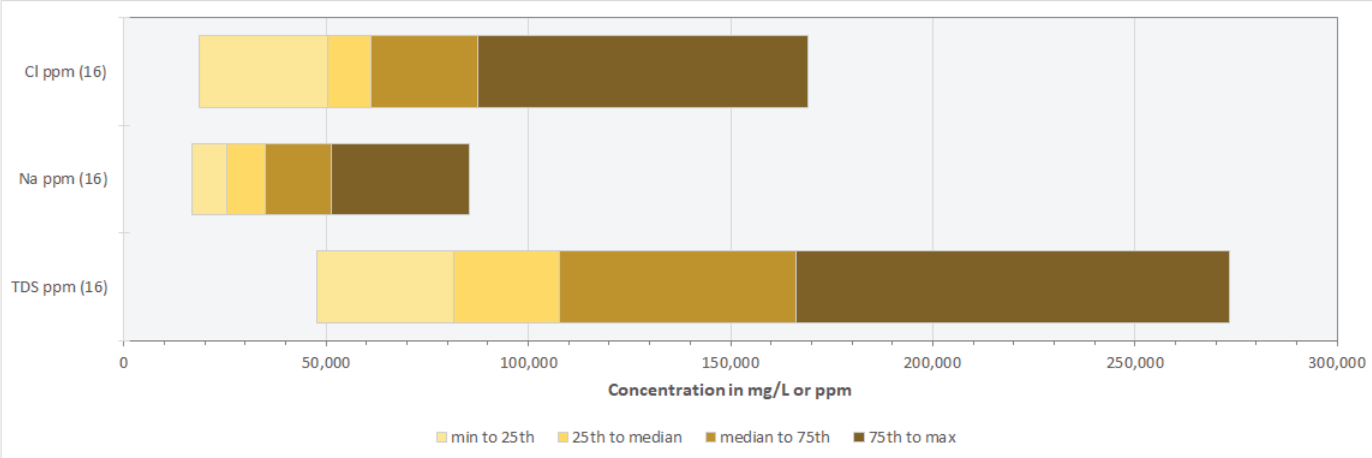


Figure 7 Concentration ranges for chloride, sodium, and TDS from 16 produced water samples in the STACK

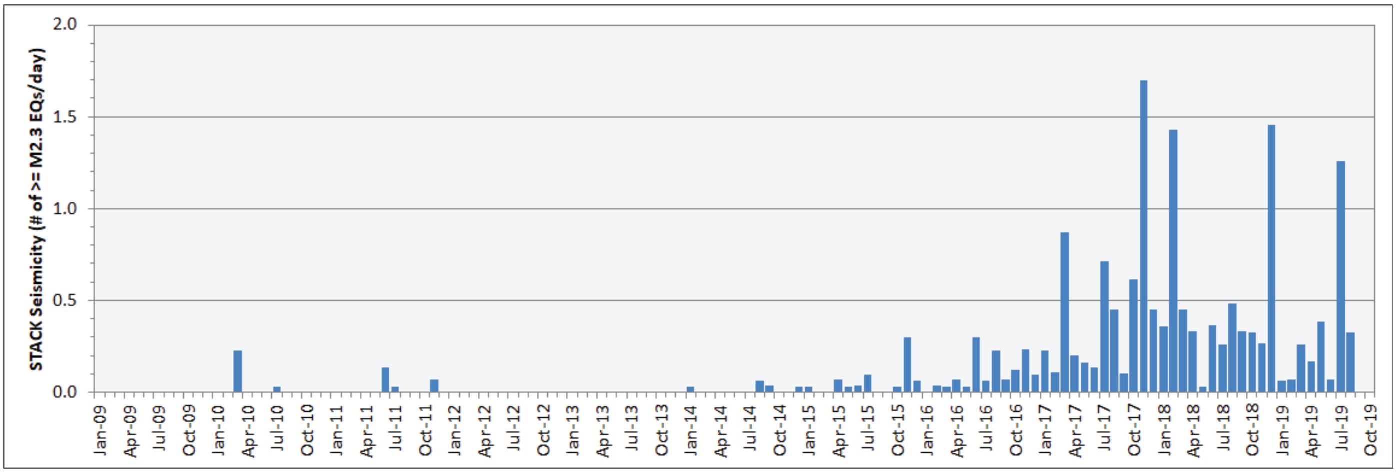


Figure 8 Monthly seismicity rate in the STACK Counties

a mean SWD rate of about 4500 BPD per well.

Collective enhanced oil recovery injection (EORI) into 2R wells in the STACK was relatively constant at about 100,000 BWPD from 2009 to 2018 (Figure 6). It appears that between 50 and 60 EORI (i.e., 2R) wells were active during the 2009–2018 timeframe, with the Atokan-Morrowan and Mississippian zones having the highest rates of injection. If we assume that all produced water is either reinjected into 2R or 2D wells then there is a maximum of about 750,000 BWPD being co-produced with oil and gas in the STACK region or at a maximum rate of about six barrels of H_2O per barrel of oil (e.g., 6 H_2O:oil).

3.4 PRODUCED WATER QUALITY IN THE STACK

Optimal produced water treatment strategies are highly dependent on water quality measures, such as TDS. In addition, reservoir or geomechanical models depend on parameter inputs, such as density, that are a function of water quality. So, for many reasons it is useful to compile produced water quality data at the sub-regional scale and to characterize the produced water by producing zone/formation. Analytical results for produced water quality samples were compiled for 16 samples that were submitted to OCC. Produced water samples were derived from a few zones (number of samples) including Multiple-Undifferentiated (4), Other or Unspecified (9), Missourian (1), Desmoinesian (1), and Mississippian (1). Figure 7 summarizes, for example, the highly variable TDS concentrations (47,700–273,496 ppm) and median concentrations of chloride (60,993 ppm), sodium (34,852 ppm), and TDS (107,718 ppm).

3.5 SEISMICITY RATE IN THE STACK

The monthly seismicity rate was calculated

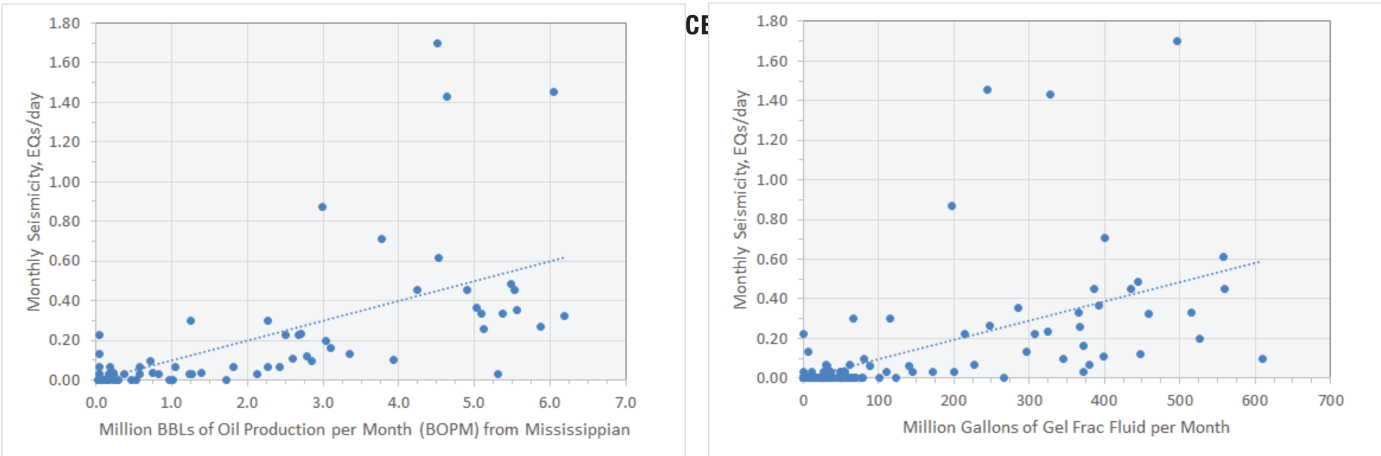


Figure 9a Monthly Correlation of Mississippian oil production versus Seismicity Rate, 9b Monthly Correlation of Gel Frac Fluid Injection versus Seismicity Rate

from the OGS Earthquake Catalog assuming that the magnitude of completeness is M2.3. There was one or more earthquakes of ≥M2.3 in 17 out of 85 months from January 2009 to January 2016; however, there was one or more earthquakes of ≥M2.3 in 45 consecutive months from February 2016 to present (October 2019). The highest seismicity rate of 51 ≥M2.3 earthquakes occurred in November 2017, or 1.7 EQ/day (Figure 8).

3.6 CORRELATIONS OF FLUID INJECTIONS AND PRODUCTIONS VERSUS SEISMICITY IN THE STACK

Figure 8 shows an apparent increase in seismic activity in the last five years (2014–2018) versus the previous five years (2009–2013). Figures 2–6 illustrate similar relative increases with regard to fluid production and injection. Because many of the OCC directives are based on scientific studies that, in general, demonstrate spatial and temporal correlations between fluid management and seismicity in Oklahoma, it is important to systematically and quantitatively evaluate various injection and production activities that may influence the state of stress in the subsurface. The Pearson correlation coefficient (R-squared) allows for an unbiased measure of the strength of correlations between independent and dependent variables. R-squared values closer to one indicate a stronger correlation. The 10 highest R-squared values were calculated for: SWD into Permian (R^2 of 0.4670), Mississippian Oil Production (R^2 of 0.4646), Gel Frac Injection (R^2 of 0.4608), Desmoinesian Oil Production (R^2 of 0.4463), SWD into Dev to Mid Ord (R^2 of 0.4269), Mississippian Gas Production (R^2 of 0.4259), EORI into Arbuckle (R^2 of 0.4158), SWD into Virgilian (R^2 of 0.4010), Fluid Frac Injection (R^2 of 0.3732), and X-Link Frac Injection (R^2 of 0.3608). Monthly data for two factors that have the most significant correlation to seismic activity are illustrated in Figure 9a and 9b.

These R^2 values may not qualify as a strong relationship in some situations, but calculation of the F-statistics indicate that all of these top 10 R^2 values are significant. The critical value is 1.5 for an array of variables with 119 degrees of freedom, and F-statistic values for nearly all factors greatly exceed the critical value for a 99% confidence interval. The five highest F-statistic values are for Mississippian Oil Production with no time lag (F of 145.1), Gel Frac Injection with 2-month time lag (F of 142.7), EORI into Arbuckle with 5-month time lag (F of 128.1), Mississippian Gas Production with no time lag (F of 127.4), SWD into Dev to Mid Ord with no time lag (F of 127.2). Given the F-statistics, we can reject the null hypothesis that seismic activity is not related to each of the dependent variables. In other words, nearly all of the production and injection factors are correlated to seismicity rate and are, arguably, factors that affect seismicity. However, because several factors are cross-correlated, it is difficult to say which are truly independent variables.

4. CONCLUSIONS

Oil and gas activity including exploration, drilling, and production from unconventional plays has dramatically increased in the U.S. since the year 2000. Some regions, including much of Oklahoma, have seen increases in produced water volumes for more than a decade and subsequently have had issues with produced water management. For example, wells completed in the Hunton and Mississippian zones in central and northern Oklahoma were notoriously dewatered starting as early as 2005 because of the high ratio of H_2O:oil, hence, electric submersible pumps (ESPs) generated large volumes of produced water from these wells. Historically high seismicity rates were concurrent with oil and gas activity and reportedly related to saltwater disposal into wells completed in the Arbuckle zone. However, many other natural processes and human activities may alter the stresses on seismogenic faults in the subsurface, so it is important to systematically evaluate or correlate numerous factors to decipher the relationships.

The STACK in Oklahoma overlaps the north Anadarko Basin and the Anadarko Shelf where the Mississippian and Woodford are the most productive zones for oil and gas. So, the STACK may be prone to produced water management challenges. In this study, we compiled monthly production and injection data in the STACK and correlate these data to monthly seismicity rates. Because of new well completions there were increases in hydraulic fracturing fluid injection, oil production, gas production, and saltwater disposal in the last decade. There was also an apparent increase in seismicity for earthquakes of ≥M2.3 in the STACK in 2014–2018 compared to 2009–2013. Pearson correlation coefficients and F-statistics indicate that numerous factors are correlated with seismicity and significant, but Mississippian Oil Production and Gel Frac Injection are most strongly correlated and most significant. Many of the human activities that correlate to seismicity are cross-correlated, so additional analyses and modeling studies are required to understand the mechanisms that have the greatest effect on subsurface stresses.

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About the Author

Dr. Kyle E. Murray is a Hydrogeologist for the Oklahoma Geological Survey and Adjunct Faculty for the ConocoPhillips School of Geology and Geophysics at the University of Oklahoma.

As the OGS Hydrogeologist, he investigates physical and chemical properties of geologic materials that store and produce fluids, and conducts regional-scale studies of water, earth, and environmental resources.

Water management in the energy industry is his current primary research area, which includes the study of water use in exploration and production, co-production of petroleum and water, saltwater management, disposal, recycle, and reuse.

Because of the recent increase in seismic activity in Oklahoma, Dr. Murray is partnering with other geoscientists to understand relationships between geologic factors, resource management, and seismicity.

OGS hosts Enhanced Oil Recovery (EOR) Technical and Core Workshop

In November 2019, the Oklahoma Geological Survey (OGS) played host to a Technical Session and Core Workshop that had over a hundred people in attendance. The technical session was on the first day and explored enhanced oil recovery (EOR) with an emphasis on mostly tight sandstones, in particular, the Hoxbar Group of rocks in the southern Oklahoma and STACK/SCOOP/Merge areas in the Anadarko Basin of Oklahoma. The Pennsylvanian (Missourian) Hoxbar Group is economically important to the Oklahoma petroleum industry. In the Anadarko Basin the Hoxbar Group (e.g., Marchand sandstone) has been a prolific producer of oil and gas.

Technical presentations included sedimentology, reservoir quality, sequence stratigraphy, geochemistry, geomechanical rock properties and integrated depositional and diagenetic evaluation of the tight sandstones applied to EOR. Reservoir heterogeneity and mineralogy (as related to petrophysics) are important components used to evaluate EOR. The workshop focused on the key learnings from both operators and researchers on tight sandstones and associated shales directly relating to EOR practices. The results of this work can be applied to other tight sandstones as an analog worldwide.

The second day of the workshop was a half-day core workshop at the Oklahoma Petroleum Information Center (OPIC). Cores were presented from several key wells of the Hoxbar Group of rocks from Caddo, Grady, Stephens and Carter Counties. The Hoxbar cores (Wadw, Medrano, Marchand, Melton,

and Cottage Grove Sandstones, Culp Oolitic carbonate and the associated mudstones) were viewed to compare the lithofacies changes regionally to examine their characteristics, and to see how the lithofacies (lithology) correlate to well logs.

David Brown, OGS Associate Director, said, "From all appearances it looked like knowledge transfer and professional networking were in fine form during the workshop. The discussions around our OPIC core on day-2 were especially exciting and highly interactive. I want to thank all attendees and presenters for making this a successful workshop. I also want to give special thanks to our OGS team for making this event possible. The OGS has proudly facilitated these kinds of forums for many years, and we look forward to continuing in that role."

For further information, please contact Dr. Seyedolali at OGS; Office: 405-325-8035; Email: abeyed@ou.edu.

Future workshops will be announced on the OGS website, as well as in the Oklahoma Geology Notes.

OGS History Part 3: A new state — and its geological survey — is born

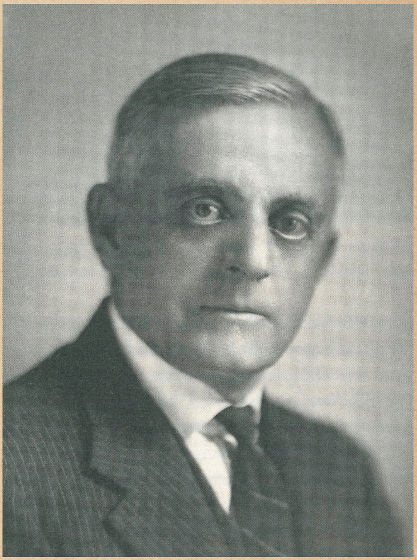
By
Ted Satterfield
Editor, Oklahoma Geological Survey

By the time the U.S. Congress passed the enabling act, mapping out the steps the Oklahoma and Indian Territories needed to take to be granted statehood, the population of Oklahoma was roughly four times the size of any other state when it was admitted to the union (Gittenger, 1939 p. 256). The march toward statehood was slow, in part, due to concerns over how granting Oklahoma statehood would impact the balance of power in Washington, but it also was due to the unusually complicated issues involving Indian Territory. At the heart of these difficulties was the allotment of land to members of tribes in eastern Oklahoma, and taxation on those lands (Dott, 1945, p. 194). Further, there were tremendous amounts of "segregated land" in Indian Territory, which was land excluded from allotment due to its value in coal, asphalt, or timber (Debo, 1940, p. 21-25). Most of the nations in Indian Territory favored the establishment of statehood separate from Oklahoma Territory, but by 1906, it was clear that the U.S. Congress was only willing to consider statehood for the Twin Territories together (Hurst, 1957, p. 1-5).

The Oklahoma Constitutional Convention

OU Geology Club in 1906. Dr. Charles Gould is seated on the far right.

began on November 20, 1906 and concluded on March 15, 1907. It was an exceptionally contentious convention, filled with bitter disagreements over prohibition, suffrage, and county boundaries, to name just a few of the thorny issues confronted at the convention (Hurst, 1957, p. 1-5). Yet, during the fiercely chaotic convention, one section that received very little resistance was Section 37 of Article 5 of the Oklahoma Constitution, which called for the creation of a state geological survey. This section called for the legislature to "provide for the establishment of a State Geological and Economic Survey," thus making Oklahoma the only state in the Union possessing a constitutional warrant for the establishment of a geological survey (Gould, 1959, p. 141). This item received only "yes" votes from members of the convention, a vote overseen by Alfalfa Bill Murray, who ironically, 23 years later, would veto all appropriations for the OGS when he became Oklahoma governor, but that's a topic for a future installment of this series (Ham, 1983).



James Shannon Buchanan

The geological survey committee at the constitutional convention was lead by W.J. Caudill, of Hobart. Other members were J.J. Sorrels, of Milton; J.B. Curl, of Bartlesville; Boone Williams, of Lehigh; and Professor James Shannon Buchanan, of Norman. Buchanan, who was head of the History Department at the University of Oklahoma, would later serve as OU's president (Harp, 2015, p. 39-44). During his unusually brief tenure as president, Buchanan would, ironically, oversee the reinstatement of the Oklahoma Geological Survey when it was first vetoed under Oklahoma governor Jack Walton in 1923-24 (Gittenger, 1950, p. 17). This event will also be addressed in an upcoming installment of this series.

Charles Gould, who in 1906 had just completed his doctorate at the University of Nebraska, met with the geological survey committee multiple times during the convention (Gould, 1932, p. 200). He aided them in formulating the plans for the establishment of the survey, as it was stated in the Oklahoma Constitution (Gould, 1959, p. 141-143). In 1907, the people of Oklahoma voted to approve the constitution, and after assuring the Constitutional Convention had completed all tasks laid out in the enabling act, Oklahoma was granted statehood, made official on November 17, 1907.

Now that the constitution was adopted and statehood was granted, Gould began work formulating the plan for how the legislature could establish the geological survey. In fact, Gould wrote the bill himself. In his autobiography "Covered Wagon Geologist," he explains that he contacted state geological surveys across the U.S., as well as in Canada and Australia, in his research to prepare for writing the bill. He wrote it specifically to avoid trouble with partisan politics. He wrote the duties broadly, but not too broadly, and then wrote that a three person board composed of the governor, the state superintendent, and the university president, would appoint the survey director. He did this in order to avoid having the survey overseen by a single individual, which would likely act out in a partisan manner, and also wanted to avoid the annoyance of dealing with a committee with too many members. This was how the OGS directors were selected until 1924, when oversight was placed under the regents of higher education.

GEOLOGICAL SURVEY TO BE ESTABLISHED

DELEGATE CAUDILL, OF HOBART, SUBMITS NECESSARY CONSTITUTIONAL PROVISION.

Special to The Oklahoman.

Guthrie, Okla., Dec. 18.—Delegate Caudill, of Hobart, chairman of the standing committee on geological survey, reported to the convention this morning, submitting a provision for the constitution, which establishes a state geological and economic survey, which shall be under the control of a commission, to be provided by the legislative assembly, to consist of three members to be appointed by the governor. This commission shall have charge of the survey and shall appoint as state geologist, a geologist of established reputation. The survey shall have for its object an examination of the geological formation of the state, with special reference to building stone, ore, soils, road metal, coal, oil, gas and other mineral substances. There shall be prepared and published from time to time such reports as the commission may deem expedient, and it is provided that the first legislature shall make provision to carry into effect these constitutional clauses.

In presenting the report Delegate Caudill explained that the committee had held weekly meetings, and had heard addresses from the topographer of the United States geological survey department and of Oklahoma, and from the geologist of the Oklahoma State university and others interested in the work.

The above newspaper article announces the constitutional convention's plans to establish a geological survey in December 1906.

With little resistance in the house or senate, the bill Gould wrote was approved, as written, with no votes against it. It was signed into law by Governor Charles Haskell on May 29, 1908. There remained only one final step before work could begin: appointing a director.

Governor Charles Haskell

Gould mentions how the chaotic nature of the new state meant delays for most everything legislators established, and how it remained unclear who would be director of the state survey or when work could begin. That is until Gould wound up on the same train as governor Haskell in July of 1908. Haskell asked Gould on the train to explain to him the natural resources in Oklahoma. Gould spoke to him for about 10 minutes, hitting the highlights, and Haskell told him to come meet with him Monday morning in Guthrie, which was the state capital at the time. When the train arrived Haskell proceeded to deliver a speech, promoting the potential economic growth that could come from developing the resources Gould had mentioned to him on the train.

Gould arrived on Monday morning, and the board that oversaw the survey was there. OU President Evens quickly nominated Gould as director and within minutes the committee had agreed, having not mentioned any other potential candidates.

The above photo shows all representatives elected to the Oklahoma Constitutional Convention, which began meeting in November of 1906 in Guthrie. Standing at the podium on the left is convention president, and future Oklahoma governor, William "Alfalfa Bill" Murray.

Since Gould had written both the act and the bill, it is perhaps not surprising that he suspected he'd be appointed director, and in fact, came to the meeting with a detailed plan of where to begin. The date was July 25, 1908, which was just three days after Dr. Gould's 40th birthday. Finally, all obstacles had been cleared, and the Oklahoma Geological Survey was officially off and running.

In the next installment, we'll discuss Gould first term as director.

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About the Author

Ted Satterfield became the OGS Editor in August 2015. A native Oklahoman, Ted has a diverse professional background. After receiving his master's in the Gaylord College at OU, he spent two years as a newspaper editor before switching to an academic career. For six years he was a mass communication faculty member at Northwestern Oklahoma State University, where he taught Intro to Mass communication, Photography, News Editing, and Media Convergence. He also acted as advisor to the student-media website. Ted is also an accomplished screenwriter and director, winning numerous awards, including the best short screenplay at the 2012 deadCENTER Film Festival. He and his wife, Melanie, co-wrote the stage play "Alcoholidays," which was produced in Oklahoma City in 2013, and ran through December 2015 at the Oklahoma City Civic Center. Ted is an active member of the Association of Earth Science Editors.

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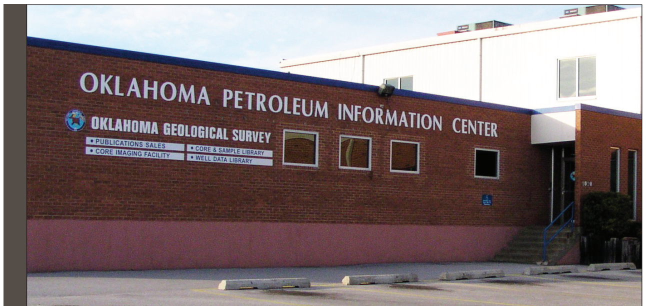

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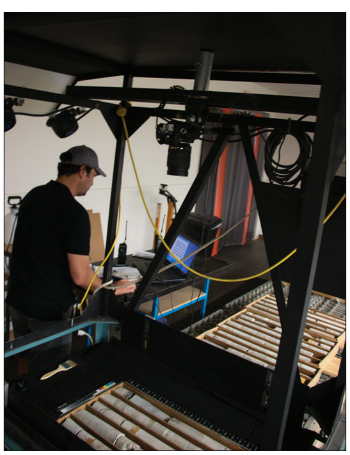

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Landslide Hazards in Eastern Oklahoma Mountains

In the next issue of the Oklahoma Geology Notes we'll have an article from Netra Regmi and Jake Walter on landslide hazards in eastern Oklahoma, an article on OGS retired geologist's book on roadside geology, and the 4th installment of the OGS history series.