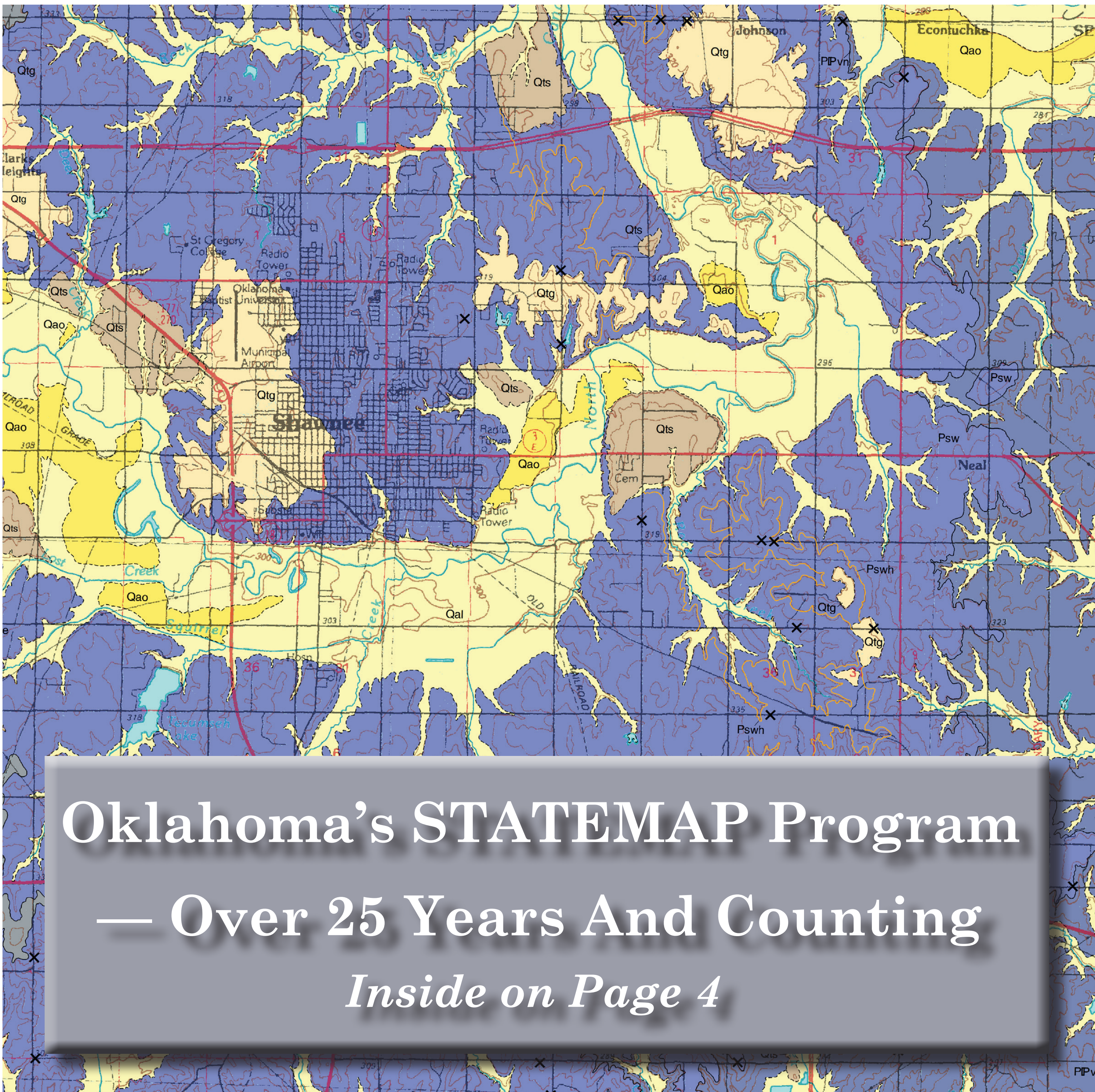
THE BLOSSM OUTREACH PROJECT : *Inside on Page 16*

OKLAHOMA GEOLOGY NOTES

VOLUME 77, NO. 4 OCTOBER-DECEMBER 2018



Oklahoma's STATEMAP Program — Over 25 Years And Counting

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OKLAHOMA GEOLOGICAL SURVEY

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The Oklahoma Geological Survey is a state agency for research and public service, mandated in the State Constitution to study Oklahoma's land, water, mineral and energy resources and to promote wise use and sound environmental practices.

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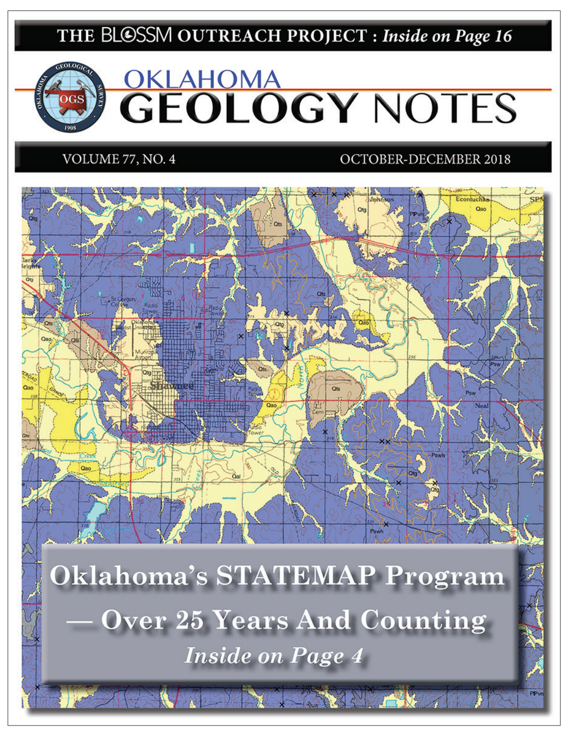

Cover Design by Ted Satterfield

From The Director

STATEMAP program, BLOSSM project, and workshop on the STACK Play

In this issue of Oklahoma Geology Notes we tell the story of one of our longest standing programs in the Oklahoma Geological Survey, the STATEMAP collaboration with the U. S. Geological Survey, and describe one of our newest, the BLOSSM (Bridging Local Outreach & Seismic Signal Monitoring) program, which brings working seismometers to school and free-choice learning centers to foster scientific literacy and enhance our seismic network. And we highlight the newest iteration of one of our other longstanding programs, an industry-oriented workshop on one of the most active oil and gas plays in the nation, the STACK Play (see the article for a definition of this acronym).

Jeremy Boak
OGS Director

The OGS has participated since the beginning of the STATEMAP program 26 years ago. Mapping the areal extent and geological character of rock units exposed at or near the surface is one of the oldest activities of the OGS, and indeed of all geological surveys. Geologic description on many scales (from continents to mine walls) has been fundamental to understanding how the Earth works, as the geometry and composition of rock types has progressively revealed deeper and deeper features of the more than four billion years of Earth history. There is a continuing need to look in greater detail, resolve discrepancies created at the borders of maps drawn by geologists with different interpretations, and apply new tools to gain greater insight, to provide information that can enable Oklahomans to use the resources beneath their feet more efficiently, wisely and safely. All STATEMAP products are available free at our website.

The BLOSSM Program offers free Raspberry Shake seismometers to schools, museums, libraries to help students and others understand what earthquakes are, how they are detected, and what they tell us about the Earth beneath us. Our mission includes disseminating the information we gather to the public to improve their understanding of geoscience, science in general, and its value to society. The teachers we introduced to these instruments told us that they bring science to life for the students, who conduct experiments of their own devising, personalizing the resulting knowledge. The OGS can use the information recorded by these devices to enhance our understanding of the seismic activity continuing in Oklahoma.

Our workshops for industry also support the mission to disseminate information that enables wise use of our natural resources. The September workshop focused on the rock units responsible for oil and gas drilling and production activity now expanding across the Anadarko Basin in west central Oklahoma. This new development has lifted oil production in the state to levels that surpass the previous peak in the 1980s. Presenting the latest information on this producing formation and giving a hands-on view of the rocks themselves at the Oklahoma Petroleum Information Center gives oil and gas companies of all sizes the chance to learn and improve their success rate.

Like most of our programs, each one described in this issue includes scientific investigation, interpretation and description, and an active attempt to get that information out to a wide range of Oklahomans to help them live better lives.

We also want to welcome two new members of the OGS staff. Abbas Seyedolali, petroleum geologist and organic petrographer, joined in July, and Terry Sherman, Systems Administrator, arrived in October. We are already seeing important contributions from both of them.

Oklahoma's STATEMAP Program — Over 25 Years And Counting

By

Thomas M. Stanley and Stacey C. Evans

Oklahoma Geological Survey

INTRODUCTION

This year marks the twenty-sixth anniversary of the Oklahoma Geological Survey's (OGS) STATEMAP program. To date, the OGS has completed 70 detailed 7.5' geologic maps at a scale of 1:24,000 and 24 reconnaissance geological maps at a scale of 1:100,000. Both types of geologic maps are available for free as printable PDF's and digital ArcGIS shape files on our web-site (http://www.ou.edu/ogs/maps).

The purpose of the STATEMAP program is two-fold: 1) provide detailed mapping at 1:24,000-scale in and around concentrated urban areas and their expanding suburbs. These areas need accurate 1:24,000-scale mapping that incorporates all available surface data, as well as subsurface data from drill holes and geophysics that will help define potential hazards, soil types, aggregate resources and groundwater aquifers, and can give assistance to urban planners, developers, and industry in their land-use decisions; and 2) complete and make available to the public geologic maps in areas that require modern, digital maps at a 1:100,000 scale. These are areas that require up-to-date maps, but may not be societally or scientifically important enough to warrant detailed geologic scrutiny. The current geologic maps of these areas are best described as inconsistent — characterized by inferior

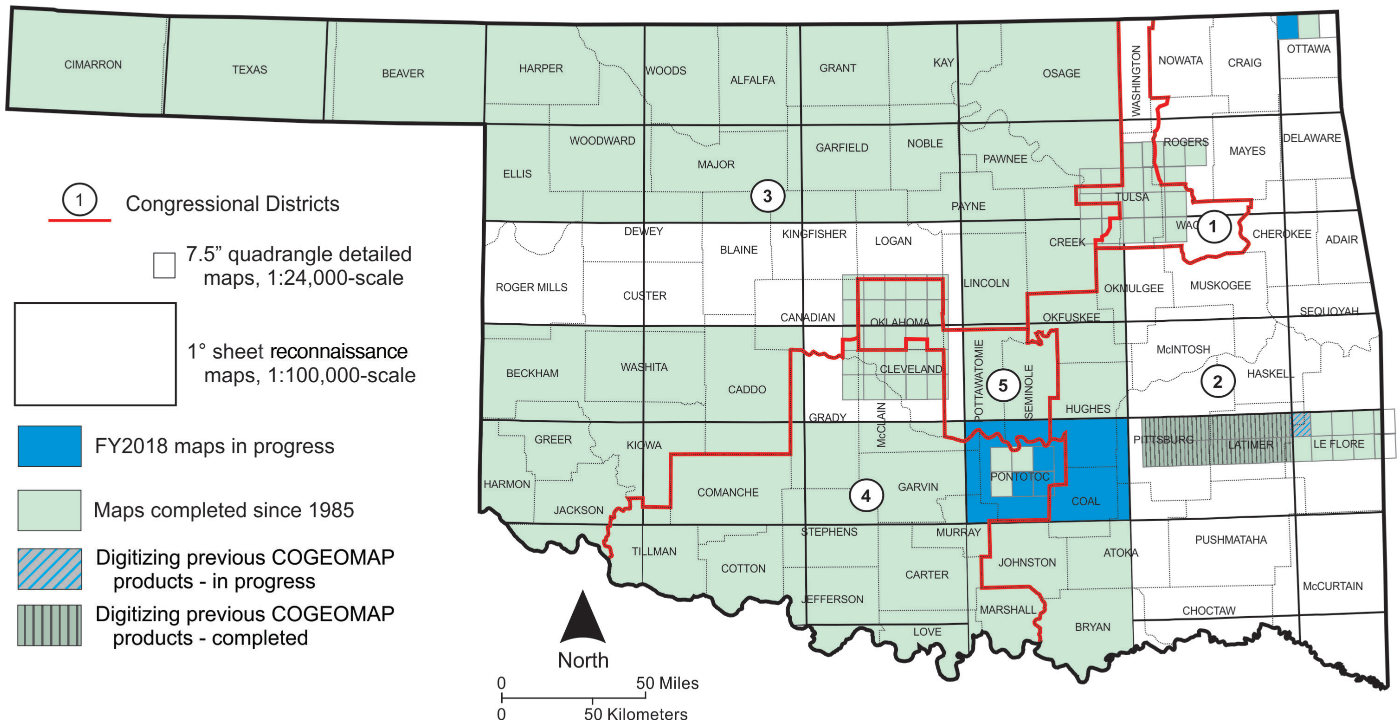

Figure 1. STATEMAP at a glance. All geologic maps products, detailed 7.5' quadrangle maps and reconnaissance 1° geology maps, produced in the COGEOMAP and STATEMAP programs. Light green represents completed maps available as PDFs or as ArcGIS shapefiles at our website. Blue represents proposed mapping projects for FY2018-2019.

quality and/or coverage, and possessing variable bases and scales. All of these maps need to be compiled, at least reconnaissance field-checked, corrected, and digitized onto a single standardized topographic base. Previous smaller scale geologic maps have been helpful to agricultural concerns in rural parts of the state, as well as aiding regional area planners with GIS capabilities in smaller urban growth areas. Moreover, these reconnaissance maps will eventually be used in the OGS's ongoing compilation of the new 1:500,000-scale geologic map of the state of Oklahoma.

This report outlines the history and current status of Oklahoma's STATEMAP projects and outlines potential mapping projects for the future.

OVERVIEW

Since 1985 the Oklahoma Geologic Mapping Advisory Committee (OGMAC) has directed the Oklahoma Geological Survey to address the state's burgeoning land-use and resource-development problems encountered in increasingly urbanized and agricultural areas. Initially, this was done through participation in the U.S. Geological Survey's Cooperative Geologic Mapping Program (COGEOMAP) by detailed mapping (Project 1 mapping) of the northern boundary of the Ouachita Mountains. The COGEOMAP program subsequently became the State Geologic Survey Mapping component of the cooperative program (i.e., STATEMAP) in 1992 when the National Geologic Mapping Act (NGMA) was signed into

OGS ONLINE

To view or download STATEMAP quadrangles, and other OGS maps, go to: www.ou.edu/ogs/maps

Federal Fiscal Year	Project Map(s), Scale	State Dollars	Federal Dollars	Total Project Dollars
1993	•Heavener and Bates Quadrangles; Le Flore County. 1:24,000	$23,732	$20,000	$43,732
1994	•Adamson and Hartshorne Quadrangles; Pittsburg County. 1:24,000	$61,844	$50,000	$111,844
1995	•Krebs and Hartshorne SW Quadrangles; Pittsburg County. 1:24,000	$80,659	$30,000	$110,659
1996	•McAlester and Savanna Quadrangles; Pittsburg County. 1:24,000 •Watonga and Foss Reservoir 1° sheets; Ellis, Roger Mills, Beckham, Dewey, Custer, Blaine, Kingfisher, Caddo, and Canadian Counties. 1:100,000	$69,104	$68,967	$138,071
1997	•Piedmont, Bethany NE, Edmond, and Arcadia Quadrangles; Kingfisher, Logan, Canadian, and Oklahoma Counties. 1:24,000 •Boise City 1° sheet; Cimarron and Texas Counties. 1:100,000	$95,482	$86,433	$181,915
1998	•Bethany, Britton, Spencer, and Jones Quadrangles; Canadian and Oklahoma Counties. 1:24,000 •Guymon and Beaver 1° sheets; Beaver and Texas Counties. 1:100,000	$113,587	$95,158	$205,745
1999	•Mustang, Oklahoma City, Midwest City, and Choctaw Quadrangles; Canadian and Oklahoma Counties. 1:24,000 •Buffalo 1° sheet; Harper, Woods, Ellis, and Woodward Counties. 1:100,000	$70,642	$79,644	$150,286
2000	•Oklahoma City SW, Oklahoma City SE, Moore, and Franklin Quadrangles; Canadian, Cleveland, Grady, and McClain Counties. 1:24,000	$47,028	$45,966	$92,994
2001	•Blanchard, Newcastle, Norman, and Denver Quadrangles; Canadian, Cleveland, Grady, and McClain Counties. 1:24,000 •Woodward and Fairview 1° sheets; Alfalfa, Blaine, Dewey, Ellis, Garfield, Grant, Kingfisher, Major, Woods, and Woodward Counties. 1:100,000	$167,804	$121,422	$289,226
2002	•Luther, Horseshoe Lake, Harrah, Stella, and Little Axe Quadrangles; Cleveland, Lincoln, Logan, Oklahoma, and Pottawatomie Counties. 1:24,000 •Alva and Elk City 1° sheets; Alfalfa, Beckham, Custer, Garfield, Grant, Greer, Harmon, Kiowa, Roger Mills, Washita, Woods, and Woodward Counties. 1:100,000	$130,123	$124,494	$254,617
2003	•Claremore and Sageeyah Quadrangles; Rogers County. 1:24,000 •Anadarko, Altus and Vernon 1° sheets; Caddo, Canadian, Custer, Greer, Kiowa, Harmon, Jackson, Tillman and Washita Counties. 1:100,000	$121,572	$110,789	$232,361
2004	•Collinsville and Sperry Quadrangles; Rogers and Tulsa Counties. 1:24,000 •Lawton 1° sheet; Caddo, Comanche, Cotton, Grady, Kiowa, Stephens, and Tillman Counties. 1:100,000	$94,069	$86,231	$180,299
2005	•Catoosa and Mingo Quadrangles; Rogers, Tulsa, and Wagoner Counties. 1:24,000 •Picher Quadrangle; Ottawa County. 1:24,000 •Burkburnett sheet; Comanche, Cotton, Jefferson, Stephens, and Tillman Counties. 1:100,000	$148,742	$137,562	$286,304
2006	•Oneta and Coweta Quadrangles; Wagoner County. 1:24,000 •Ponca City 1° sheet; Garfield, Grant, Kay, Noble, Pawnee, and Osage Counties. 1:100,000	$112,932	$102,330	$215,262
2007	•Broken Arrow and Leonard Quadrangles; Tulsa and Wagoner Counties. 1:24,000 •Enid 1° sheet; Garfield, Kingfisher, Lincoln, Logan, Noble, and Payne Counties. 1:100,000	$97,142	$86,540	$183,682
2008	•Bixby and Sapulpa South Quadrangles; Tulsa and Creek Counties. 1:24,000	$84,714	$83,127	$167,841
2009	•Sand Springs and Wekiwa Quadrangles; Tulsa and Osage Counties. 1:24,000 •Pauls Valley 1° sheet; Cleveland, Garvin, Grady, McClain, Murray, Pottawatomie, and Stevens Counties. 1:100,000	$101,479	$95,909	$197,388
2010	•Sapulpa North and Lake Sahoma Quadrangles; Tulsa and Creek Counties. 1:24,000	$110,362	$108,153	$218,515
2011	•Jenks and the Kellyville Quadrangles; Tulsa and Creek Counties. 1:24,000 •Conjoined Ardmore and Gainsville 1° sheets; Carter, Jefferson, Love, Murray, and Stevens Counties. 1:100,000	$102,631	$97,452	$200,083
2012	•Tulsa Quadrangle; Tulsa County. 1:24,000 •Conjoined Tishomingo and Sherman 1° sheets; Atoka, Bryan, Carter, Coal, Johnston, Love, Marshall, and Murray Counties. 1:100,000 (First year of a two year project)	$99,979	$95,038	$195,017
2013	•Vanoss Quadrangle; Pontotoc and Seminole Counties 1:24,000. •Conjoined Tishomingo and Sherman 1° sheets; Atoka, Bryan, Carter, Coal, Johnston, Love, Marshall, and Murray Counties. 1:100,000 (Second year of a two year project)	$80,481	$76,500	$156,981

Continued on next page

Federal Fiscal Year	Project Map(s), Scale	State Dollars	Federal Dollars	Total Project Dollars
2014	•Roff North Quadrangle; Pontotoc County, 1:24,000. •Pawhuska 1° sheet; Kay, Noble, Osage, Coal, and Pawnee Counties, OK, 1:100,000. •Digitizing previous COGEOMAP products: Red Oak Quadrangle; Latimer County, OK,. 1:24,000	$86,081	$78,996	$165,077
2015	•Ada Quadrangle; Pontotoc and Seminile Counties, OK, 1:24,000 •Keystone Lake 1° sheet; Creek, Noble, Osage, Pawnee, Payne, and Tulsa Counties, OK, 1:100,000. •Digitizing previous COGEOMAP products: Talihina Quadrangle; Latimer and Le Flore Counties, OK. 1:24,000	$75,179	$68,160	$143,339
2016	•Bristow 1° sheet; Creek, Lincoln, Noble, Okfuskee, Okmulgee, Payne, and Tulsa Counties, OK, 1:100,000. •Digitizing previous COGEOMAP products: Le Flore Quadrangle; Latimer and Le Flore Counties, OK. 1:24,000	$76,292	$69,772	$146,064
2017	•Shawnee 1° sheet; Hughes, Lincoln, Okfuskee, Okmulgee, Pottawatomie, and Seminole Counties, OK Counties, OK, 1:100,000. •Digitizing previous COGEOMAP products: Blackjack Ridge Quadrangle; Le Flore County, OK. 1:24,000	$50,121	$47,993	$98,114
2018	•Miami NW Quadrangle; Ottawa County, OK, 1:24,000. •Ada 1° sheet, Atoka, Coal, Garvin, Hughes, McClain, Murray, Pontotoc, Pottawatomie, and Seminole Counties, OK, 1:100,000. (First year of a two year project). •Digitizing previous COGEOMAP products: Summerfield Quadrangle, Le Flore County, OK. 1:24,000.	$102,462	$100,958	$203,420
	GRAND TOTAL	$2,398,614	$2,173,223	$4,571,837

Table 1. Yearly expenditure of federal and state money since the inception of the Oklahoma Geological Survey's STATEMAP program in 1993.

law. Consequently, STATEMAP represents a coordinated fund-matching program providing federal assistance to state geological surveys in support of new mapping and digital compilation of existing maps (Table 1; Figure 1).

With OGMAC's recommendation for continued detailed mapping along the front range of the Ouachita Mountains, our mapping endeavors shifted east toward the McAlester region. Mapping in this area was conducted with an emphasis on land-use issues surrounding the growing McAlester population, as well as elucidating energy resources related to the oil and gas industries of the Arkoma Basin and solving stratigraphic problems associated with the lower Pennsylvanian section within the region (Suneson et al., 2001).

By 1996, in addition to detailed mapping of critical land-use areas, OGMAC also recommended start-up of a broader mapping program (Project 2 mapping) that would ultimately form the basis of a new 1:500,000-scale state geologic map of Oklahoma. Whereas Project 1 represents detailed mapping at 1:24,000 scale, Project 2 consists of contemporary reconnaissance mapping mixed with a compilation of preexisting geologic maps of an area (usually done at various scales and projected onto differing bases) and then seamlessly digitizing all pertinent geologic information, old and new alike, onto a single 1:100,000-scale topographic base (i.e., 1° topographic sheets). Project 2 mapping began in the far northwest and panhandle areas of Oklahoma with plans to continue an east-by-southeast sweep of the state in subsequent years, and concluding the project once mapping of the Oklahoma parts of the De Queen-Idabel 1° sheets were finished (Figure 2). The northwest was chosen because the geology in these areas consists of a well-known and well-studied Permian section that is regionally consistent and structurally simple (Suneson et al., 2001; Stanley and Miller, 2004).

Unfortunately, the initial attempt at taking previously published geologic maps of variable scales and authored by different geologists at

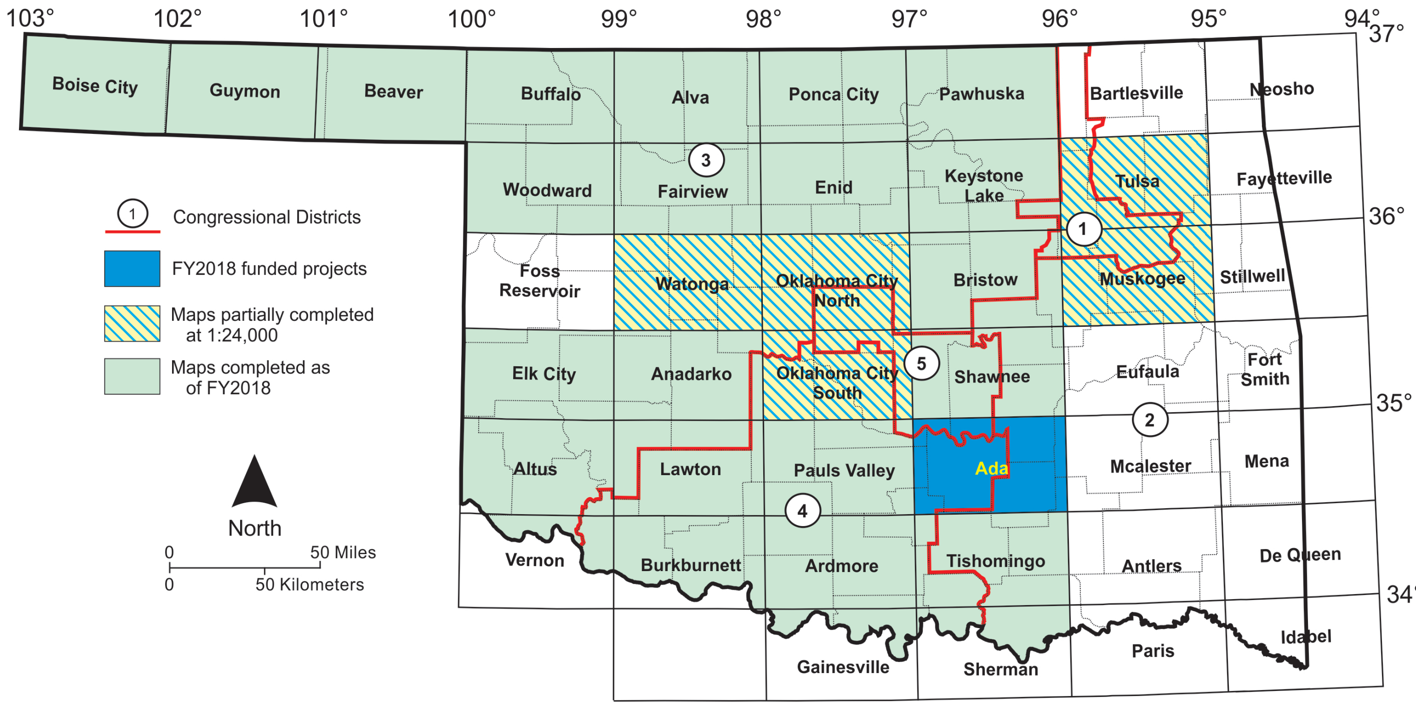

Figure 2. Reconnaissance, 1° geology mapping detail. Light green represents completed maps available as PDFs or as ArcGIS shapefiles at our website and blue represents proposed mapping projects for FY2018-2019. Blue and yellow striped areas represents partially completed 1° geology maps with detailed, 7.5' geology maps.

different times in state history, and then compiling them onto a uniform topographic base was met with difficulty in a number of areas. The use of compilation methods that overly relied on office procedures, such as mapping from air photos, to the exclusion of field checking lead to problematic maps. This was particularly evident in areas having highly dissected terrains, where the resulting digital map product had radically discordant geology and geologic contacts relative to the topographic base. The immediate solution to this problem was to insert reconnaissance field checking into the compilation process, which stabilized the cartographic difficulties in transferring variable geologic sources onto a uniform base.

Besides expanding Oklahoma's STATEMAP program to include reconnaissance mapping, after 1996 the Federal STATEMAP program shifted emphasis away from detailed mapping in areas that predominantly stressed development of energy resources (particularly in areas with low population growth), to a program that emphasized problems related to increased urbanization, and their related land- and water-use concerns. Considering the new policy, once detailed mapping of the Ouachita front range and McAlester area was complete, OGMAC recommended a detailed geologic mapping program of the Oklahoma City metropolitan area (OCMA). The following year, OGS submitted an initial three-year, four quadrangles/year plan starting in the northern part of the OCMA (Table1; Figure 1). The main purpose of the new program was to address environmental and engineering concerns encountered due to increased population growth and related housing and industrial development, as well as solving some stratigraphic problems encountered in the Lower Permian (Leonardian) part of the stratigraphic section in this area.

With the success of the first three-year plan, in 1999 OGMAC recommended, and OGS submitted, a second three-year plan to complete the southern tier of quads in the OCMA, as well as an additional five quadrangles along the eastern boundary of the area (Table 1; Figures 1 and 3).

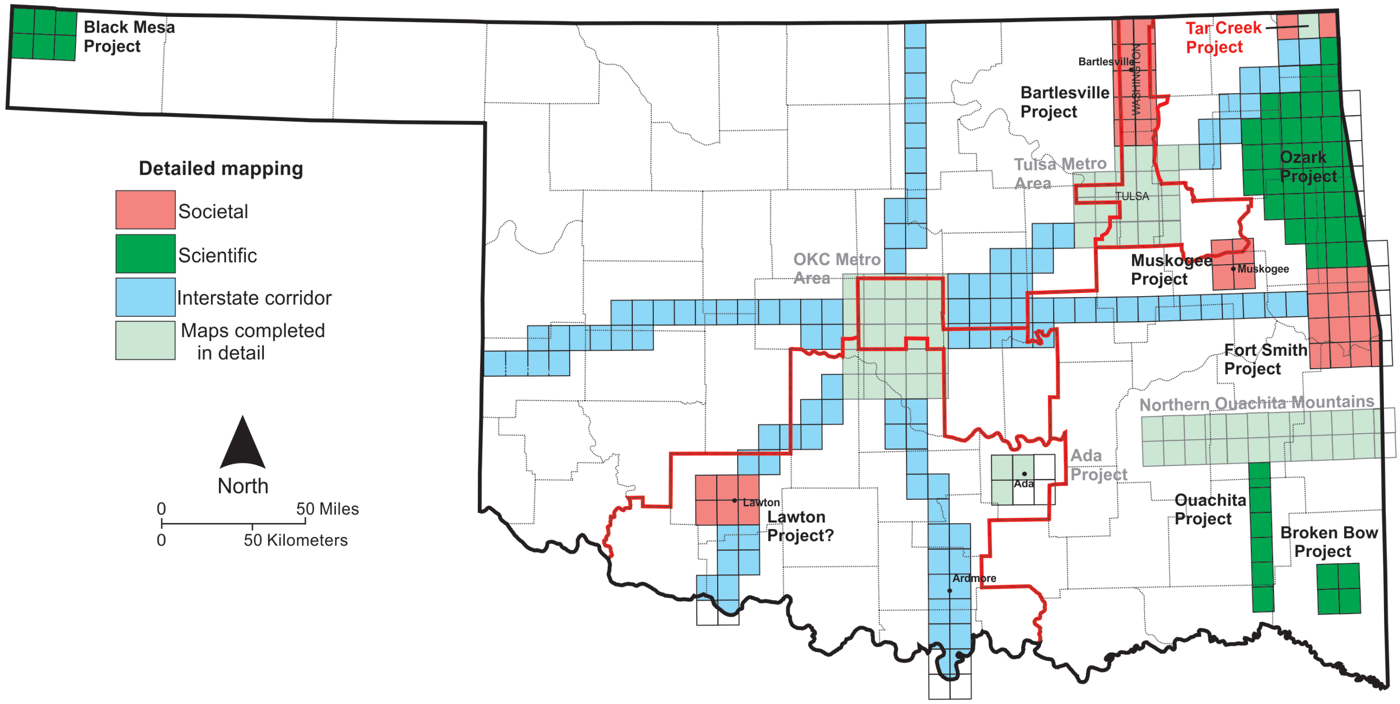

Figure 3. Detailed, 7.5' quadrangle mapping—past and future. Detailed mapping projects broken out on the basis of whether they primarily benefit societal concerns (usually focused on urban areas with expanding populations), or whether they address more or less geologic issues and questions (dark green). Light green represent completed detailed mapping projects.

These additional five quads were added due to the proposed "outer-loop" interstate bypass through this area by the Oklahoma Department of Transportation. If built, the outer-loop bypass would have been the focus of new business and residential development in this eastern-most area.

As of FY2002, all proposed mapping in the OCMA was completed, resulting in 25 detailed, 1:24,000-scale surficial geologic maps, complete with cross-sections and detailed descriptions of mapped units (Figures 1 and 3). Once this project was completed, the logical direction to continue Project 1 mapping was in the Tulsa metropolitan area (TMA).

In FY2003 the first of a three-year plan to map the TMA was implemented, starting in the northeast part of the proposed area, and then continually moving west-southwest in subsequent years (Table 1; Figures 1 and 3). The purpose of starting in the northeast and working west was to provide for the full benefit of studying the Pennsylvanian section from its lowest stratigraphic exposures in the study area with minimal amount of cover from intense urbanization.

The TMA offered a different set of problems than those encountered in the Oklahoma City region. One, the Pennsylvanian section around Tulsa is a far more complex suite of continental and marine sedimentary rocks than those previously encountered. This area represents somewhat of a confluence between the more predominantly continental-type sediments transported and then deposited from the Ouachita and Ozark Uplifts to the south and east, and the more predominant marine-type Pennsylvanian sediments common to the north and west of Tulsa. Second, the TMA possessed subtle, yet mappable structure. As evident from older maps (Oakes, 1952; Bennison et al., 1972), most of the obvious structure is in the form of broad folding, but faulting of small to moderate displacement is also present. To accurately map these structures, careful attention was given to outcrop description, tracing key marker beds within the section, and carefully noting broad regional trends in outcrop patterns. This was another reason why the OGS only averaged two quads/year in the TMA, as opposed to the four quads/year in the OCMA.

After 10 years the TMA mapping project was completed with great success, producing 19 detailed geologic maps with cross sections and detailed rock descriptions (Figures 1 and 3). Many of the subtle structures hinted at in previous maps were borne out, as well as discerning other structural complexities previously unrecognized, including broad, gentle, mostly west and northwest trending monoclines and folds in the Claremore, Sageeyah, Collinsville, Sperry, and Tulsa quadrangles and north-northeast trending normal faults in the Claremore, Sageeyah, Oneta, and Coweta quadrangles. The Tulsa Pennsylvanian section was also revamped somewhat by incorporating new formations of the Lost Branch and Memorial that supplanted the erroneous Holdenville Formation in the TMA and areas north.

After the conclusion of the TMA project the OGS, with OGMAC's blessing, shifted sights to the Ada map project. As a continuation of our Project 1 detailed mapping, the OGS proposed an initial round of three 7.5' quadrangles (Figures 1 and 3). The most important societal concerns in the Ada area are surficial and groundwater issues, particularly water rights concerning the Arbuckle-Simpson aquifer (Puckette et al., 2009; Christenson et al., 2011).

In search of future water supplies, the Central Oklahoma Water Resource Authority, consisting primarily of communities in Canadian County, Oklahoma, proposed in 2002 to purchase water rights for the Arbuckle-Simpson aquifer, drill wells, and build an 88-mile pipeline from the Arbuckle-Simpson aquifer to Canadian County in central Oklahoma (Christenson et al., 2011). However, local residents, citizens' groups, and the National Park Service were concerned that large-scale withdrawals from the Arbuckle-Simpson aquifer would cause decreased flow in rivers and springs, which could result in the loss of water supplies, recreational opportunities and aquatic habitat. These fears led to many protests being filed with the Oklahoma Water Resources Board because of the proposed water transfer, and as a result, the Oklahoma Water Resources Board, in collaboration with the Bureau of Reclamation, the U.S. Geological Survey (USGS), Oklahoma State University, and the University of Oklahoma, managed a comprehensive multi-year study of the aquifer. Called the "Arbuckle-Simpson Hydrology Study," it was to provide the Oklahoma Water Resources Board with the scientific information needed to determine the volume of water that could be withdrawn from the aquifer while protecting springs and streams (Oklahoma Water Resources Board, 2003; Christenson et al., 2011).

Along with the hydrologic studies by federal and state agencies, and with the continued infighting over water rights within the state, the town of Ada requisitioned a study of their own to evaluate methods for securing a long-term dependable water supply independent of the Arbuckle-Simpson aquifer. This led to a feasibility study of a possible man-made reservoir, called Scissortail Lake that would be located west of the town of Ada.

Obviously, it would be beneficial for the town of Ada and for Oklahoma to have a detailed and accurate understanding of the bedrock geology flooring this proposed lake site, which was why the OGS proposed the Ada project: a multi-year, six map project around Ada, set to begin in 2014. The first stage of the project provided detailed bedrock and surficial geologic maps of the specific proposed site for Scissortail Lake and was completed in 2016. The remaining three proposed maps located south and east of Ada are presently on hold as the OGS finishes with the current Tar Creek Superfund project.

Throughout these many years of detailed mapping around various metropolitan areas, the STATEMAP program has continued with its Project 2 reconnaissance maps by publishing at least one 1° geologic map a year (Figure 2). Conservative estimates suggest we will have full 1° sheet geology coverage of the whole state within seven years. Also, plans to begin compiling all of the finished 1° geology maps, eventually incorporating those finished in subsequent years, and producing a new 1:500,000 geology map of Oklahoma will begin this fall.

PRESENT AND FUTURE MAPPING

Current mapping endeavors for Project 1 detailed mapping has shifted to finishing the Tar Creek mapping project, while Project 2 reconnaissance mapping centers on the Ada 1° sheet (Figures 1 and 2).

Three quads at the Tar Creek Superfund site were chosen due to extreme environmental degradation from tailings and slag piles related to the lead-zinc mining of the 1920's through 1940's. Previous attempts by Ken Luza of the OGS to incorporate location, attitude, and size of old mine surface and subsurface workings into GIS digital format have been successful, and it is hoped that upgrading the 1:24,000-scale geology into a GIS digital format will help further studies of this troubled area by federal and state agencies. The area of impact falls within the northern parts of three quadrangles, the Peoria, Picher, and Miami NW (oriented from east to west), and includes Lower Pennsylvanian (Desmoinesian) and Upper Mississippian (Chesterian and Meramecian) strata along the northwest flank of the Ozark Uplift. The geology of the Picher Quadrangle is already completed (Stanley and Luza, 2006), and can be downloaded from our website. Mapping on the Miami NW quad began in September 2018, and mapping on the Peoria quad will begin the subsequent year.

As for Project 2 mapping, the area encompassed by the Ada 1° sheet represents one of the more geologically complex areas of Oklahoma and includes parts of the northern Arbuckle Uplift, Cherokee Platform, and the Ouachita Mountains geologic provinces. Exposed lithologies are numerous, vary wildly in age and composition, and are disjointed by varying degrees of structural complexity. Due to these complexities, we anticipate this project to run two years to completion, rather than the single year it usually takes to map and finalize a 1° sheet.

Below are brief descriptions of future Project 1 mapping projects for our STATEMAP program. These projects were chosen based on their societal or scientific importance and organized based on the degree of their societal or scientific impact. It should be noted that the type or order of these projects is not set in stone and can change based on the changing needs of the state.

Fort Smith Project

This project probably represents the highest priority for STATEMAP after the conclusion of the Tar Creek project. Located along the southern edge of the Ozark Uplift and adjacent to Fort Smith, Arkansas, this area is extensively underlain by the Atoka Shale, an unstable unit prone to mass wasting and engineering difficulties. These engineering problems are exacerbated by the regional dips to the south. According to the Arkansas Geological Survey, outlying suburbs and reservoirs surrounding Fort Smith have been experiencing extensive problems of landslide and mass wasting of the Atoka Shale due to its unstable nature, and it is more than likely similar rock failures will occur on the Oklahoma side.

Detailed mapping of at least nine 7.5' quadrangles should cover the majority of Atoka outcrops (Figure 3). Mapping will determine the exact extent and nature of the Atoka Shale underlying the area and ascertain if there is a specific stratigraphic component associated with weaknesses in parts of the formation, or whether the problems are common to the unit as a whole.

Bartlesville and Muskogee Projects

Both areas have had very little mapping of any kind in the last half century. Detailed mapping around Bartlesville was last done by Oakes (1940) as part of a larger endeavor mapping Washington County. The area around Muskogee was never mapped in any detail; although a geologic report of the area was published by Bell (1961).

Given its proximity to Tulsa, as well as its expanding urban population (35,750 individuals as of 2017), Bartlesville seems to be the next logical area for detailed mapping after Fort Smith. Bartlesville itself can be adequately covered with four 7.5' quadrangles; however, with the addition of six more quads, the OGS could cover the whole State Highway 75 corridor with detailed geologic maps between the Kansas state line and connecting with our detailed mapping in the Tulsa project (Figure 3).

Muskogee, with an expanding population (39,223 as of 2017), is also ripe for detailed mapping at 1:24,000 scale. The town and surrounding suburbs can be adequately covered by four quadrangles (Figure 3).

Lawton Project

With a population of 96,867, Lawton ranks as the fourth largest municipality in Oklahoma behind Norman, and given that the area has had little if any geologic attention beyond what is shown on the state geologic map of Miser et al., (1954), it would seemingly be a good candidate for detailed mapping based on population growth alone (and seemingly a better candidate for detailed mapping than Bartlesville or Muskogee). However, we hesitate ranking the project higher because of the presence of Fort Sill and the Wichita Wildlife Refuge. Both areas would require granting extra privileges to allow STATEMAP geologists access to these areas. In addition, even if privileges were granted, there would still remain a large segment of area totally inaccessible due to unexploded ordinance on the Fort Sill gunnery range. As such, large tracts of land south and southeast of the Wildlife Refuge would remain blank, subsequently relegating the whole project marginally worth the effort in either time or money.

Ozark Project

This area presents several problems relative to geology that should be solved. First, the Ozark Uplift has not had an original published map since the late 1950's (Huffman, 1958), and never at the detail of a 1:24,000-scale map. Lacking significant economic interest related to oil and gas, or agriculture and water concerns, has made this region the most scientifically underdeveloped in the state. Added to this, the Mississippian within the tristate district of Oklahoma, Missouri and Arkansas has been undergoing extensive stratigraphic revision since initial work (Boardman et al., 2013). Also, there is considerable structural complexity around the margins of the platform related to middle and upper Paleozoic deformation that has been given little attention to exact timing and extent relative to the main Ouachita-Wichita orogeny. All of these problems can be solved simultaneously with blanket coverage of the area using 1:24,000-scale mapping.

Broken Bow

This area was last mapped in any detail, and incorrectly so, in the 1920's by Honess (1923). Since then, little has been done geologically at Broken Bow. The area is structurally and stratigraphically complex, and low-grade metamorphism obscures the already complicated stratigraphic relations of the rock section, and which subsequently led to incorrect structural interpretations of the area by Honess. The area is also good for collecting well-formed quartz crystals and veins that may possibly be associated with northeast and northwest trending fracture systems related to the Ouachita orogeny. Detailed mapping may provide clues if these relationships exist, and if not, at least point to other geological relations for quartz veining.

Ouachita Project

Overall, the Ouachita Mountains represent a difficult mapping region even for experienced field geologists. The area is one of the more structurally complex in the state. Understanding this complexity is impaired by a stratigraphic section consisting mostly of thick, monotonous sequences of largely indistinguishable shales and sandstones with few marker horizons needed for accurate mapping, and extensive tree and ground cover. However, even if difficult, the project could yield valuable information concerning the middle to late Pennsylvanian Ouachita orogeny, given that very little detailed mapping has been done across the region. The strategy would consist of picking a north-south line of 7.5' quadrangles, then, starting at the south end of our old COGEOMAP Northern Ouachita Mountains project, mapping one quad a year to the south. The result will be to produce a single, unique, contiguous slice map through the heart of the Ouachita Uplift.

Black Mesa

The geology of Black Mesa is unique in Oklahoma, which is exemplified as one travels west across the panhandle. Here, the flat, featureless plains give way to buttes and mesas reminiscent more of western states such as Colorado or New Mexico rather than Oklahoma. This aesthetic difference in physiography is a direct result of the unique geology found at Black Mesa (Suneson and Luza, 1999), underscored primarily by the Mesa itself, which represents a massive basalt flow that originated in southeast Colorado. Black Mesa State Park is recognized as the location of the highest point in Oklahoma. It is also historically famous as the greatest collection locality of dinosaur bones in the state, first discovered by J. Willis Stovall during the 1930's and 40's. Along with these aesthetic, historical, and geologic features, the authors have observed subtle structure (gentle warping of the strata) within the park that has been previously unreported until now. The warping may be related to the Cimarron Arch, located about 50 miles to the east in the subsurface, and suggests the Cretaceous rocks exposed in the state park represent the western limb of that buried arch.

Interstate Corridor

Oklahoma is transected by three major interstate highways, I-35, I-40 and I-44 that are vital to United States intercontinental transportation and commerce. It stands to reason having an extensive understanding of the geology flooring these vital corridors with detailed 7.5' maps would be beneficial to Oklahoma and the nation. For example, the detailed descriptions that accompany every map would provide engineers basic knowledge of available materials and character of rock mechanics underlying each of the interstates, as well as provide locations of suitable deposits of sand and gravel necessary for potential road construction sites in the foreseeable future.

CONCLUSIONS

The STATEMAP program is in its twenty-sixth year at the Oklahoma Geological Survey, and so far has been an unmitigated success. Nearly a hundred new geological maps of varying scales and levels of detail that concentrate on a number of different geologic problems have been produced so far. This success has been achieved through a two-pronged approach of detailed mapping of areas that may have potential land-use issues, coupled with reconnaissance mapping in areas with marginal quality map coverage.

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About the Authors

Tom Stanley is currently the Principal Investigator of the Oklahoma Geological Survey's (OGS) STATEMAP program, which is a 50/50 cost sharing program between federal and state governments established to foster geologic mapping in areas deemed to be of vital economic, social, or scientific interest.

Prior to joining the OGS in 1998, he received a B.S. degree in geology (1982) from Southern Illinois University—Carbondale, and an M.S. degree in geology (1984) from Kent State University.

After receiving his Master's, Tom spent twelve years as an exploration geologist working in the precious metals industry doing claim block evaluation in the Black Hills, South Dakota, and in central and southern Nevada. Then in 1998, Tom received a Ph.D. in geology from the University of Kansas.

Besides mapping the state of Oklahoma, Tom's other research interests include Oklahoma stratigraphy, sedimentology, and invertebrate paleontology.

Stacey Evans joined the Oklahoma Geological Survey as a Research Geologist in late 2014. Her primary focus is field mapping. She is currently involved in the STATEMAP project updating the geologic map of Oklahoma. Prior to joining the OGS, she gained experience as a petroleum geologist working in the Anadarko Basin, the Permian Basin, and the Gulf of Mexico shelf. Other professional interests include sedimentology, diagenesis, and paleomagnetism. Stacey received both a B.S. (2008) and an M.S. (2011) in Geology from the University of Oklahoma. During that time she did field work in Nevada, Colorado, Missouri, Wyoming, and Scotland. Stacey currently sits on the OGS's Social Media committee and the Workshop and Fieldtrip committee. She is a member of the American Association of Petroleum Geologists, Geological Society of America, and the Oklahoma City Geological Society.

The BLOSSM project aims to boost earth science education with workshops and seismographs

by
Ted Satterfield and Dr. Molly Yunker
Oklahoma Geological Survey

At Leonardo's Children's Museum last June, eleven public school teachers, and a librarian, from across Oklahoma met on a Saturday — during their summer breaks — to attend the second day of a professional development workshop hosted by the OGS, to learn about seismicity, and how they may best teach their students about Earth science. These teachers were among the first wave of educators to be part of what will be a regional and statewide rollout of a program initiative called BLOSSM. The program has been in the planning stages at the OGS for years now, but has finally taken flight, and is clearly off to a great start. The program seeks to harness Oklahoma's uptick in seismic activity over the last decade as an educational opportunity for teachers and students across the state.

The BLOSSM in Oklahoma project (Bridging Local Outreach & Seismic Signal Monitoring) aims to provide educational resources to public schools and free-choice learning environments, to foster scientific literacy, and to develop a community of citizen-scientists. Eventually, the program will distribute 100 Raspberry Shake seismographs throughout the state, into educational institutions in Oklahoma, including schools, libraries, and museums. The seismographs, in conjunction with the professional development workshops, aims to help expand teachers' understanding of seismicity, as well as earth science in general. Additionally, the program seeks to enable them to take this information and find effective ways to present it to their students, developing curricula that align with the Oklahoma Academic Science Standards.

The Raspberry Shakes are seismographs that will mostly be placed in classrooms, enabling students and teachers to see seismic activity in real time. A Raspberry Shake is made up of (1) a geophone sensor that detects weak vibrations, (2) a circuit board that collects the data that the sensor detects, and (3) a Raspberry Pi mini-computer. It is an all-in-one personal seismograph that can detect vibrations from earthquakes and other sources, even ones that are not normally felt by people. It works the same way as conventional seismic monitoring equipment, but at a small fraction of the cost.

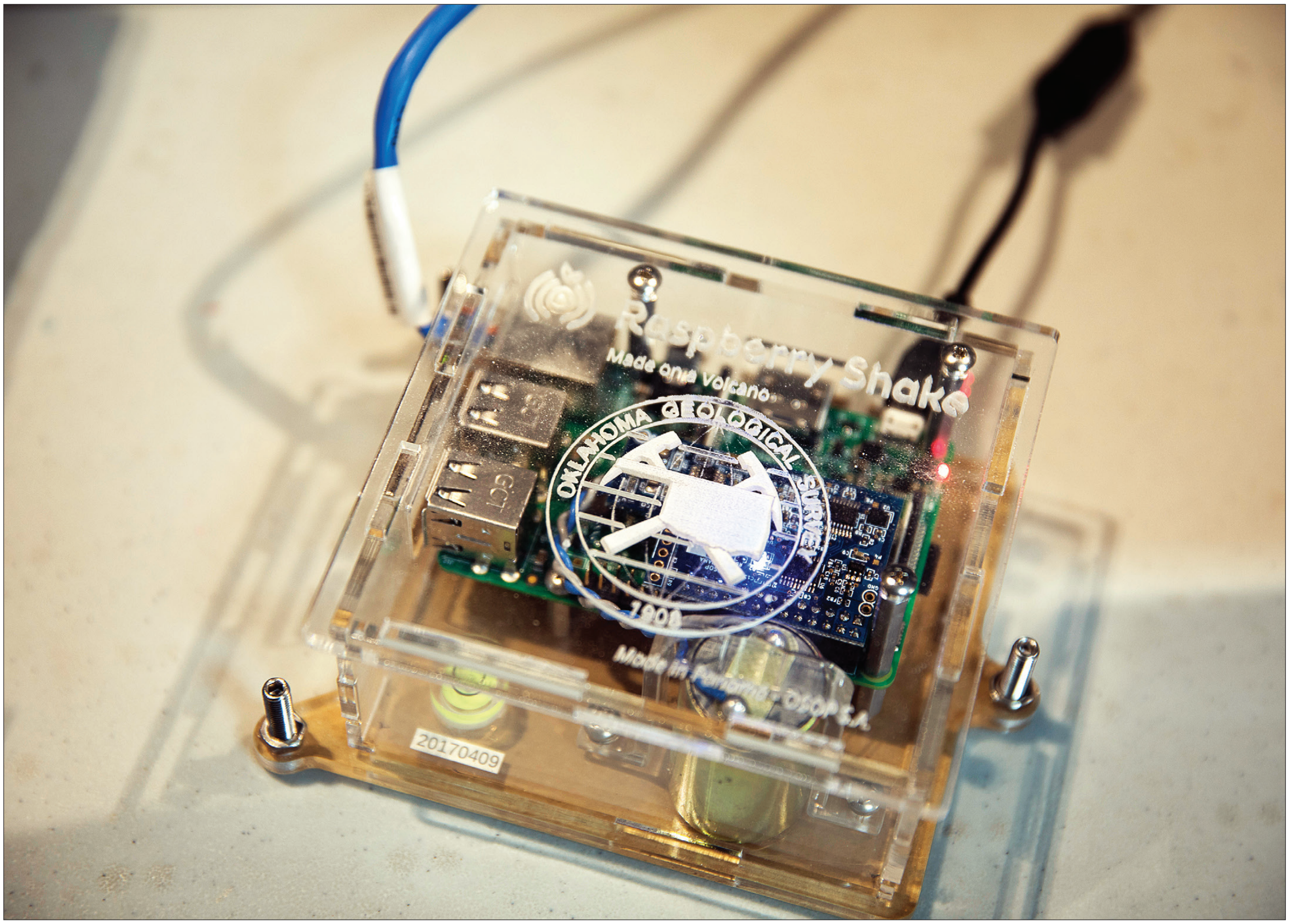


Photo of a Raspberry Shake seismograph, that will be placed in classrooms, enabling students and teachers to see seismic activity in real time

In addition to the educational benefits the Raspberry Shakes provide, they are also a valuable supplement to the OGS's statewide seismic monitoring network in regions of the state where coverage is sparse. Data collected from these seismographs are freely available to the public.

During the first day of the two-day workshop, participants received a Raspberry Shake, learned how to install it in their educational facility, and experimented with the type of data it collects. During the second day of the workshop, participants explored introductory seismology and Earth science concepts with the help of State Seismologist, Dr. Jake Walter, his undergraduate student, Sarah Sundberg, and Education & Outreach Coordinator, Dr. Molly Yunker. Participants concluded the workshop with numerous resources including lesson plans, ideas for classroom activities, a working seismograph, seismology posters and other teaching tools to aid in STEM education, as well as a new community of teachers they didn't previously know.

HOW DOES IT WORK?

The geophone sensor has a suspended mass surrounded by coiled copper wire. When the mass moves up and down, due to vibration, it generates a voltage. This voltage is then translated by the circuit board to velocity (in meters per second) over time. The visual representation of the recorded velocity reading over time is called a waveform. We can analyze the waveforms to know whether or not an earthquake has occurred.

During the workshop in Enid last June, Dr. Jake Walter, State Seismologist with the OGS, spoke on the subject of seismicity, the history of seismicity in Oklahoma, the recent seismic increase, the causes

State Seismologist, Dr. Jake Walter, addresses workshop participates at Leonardo's Children's Museum last June.

of that increase, measures taken to decrease this activity, as well as hazards and safety precautions. Dr. Walter fielded many questions, especially about what researchers believe is behind the seismicity.

As the teachers returned to their classes to implement what they'd learned at the workshops, the feedback has been overwhelmingly positive. Teachers have noted that the Shakes make science more accessible to their students.

Rachel Morgan, teacher at Fargo Public Schools, said students are excited about the Raspberry Shake in their classroom.

"The kids are genuinely surprised and amazed that this little box in the basement at Fargo, Oklahoma can pick up earthquakes that happen so far away," she said.

Kristi Carlucci, Coordinator of Community Education at Oklahoma City Community College, first used the Raspberry Shake with kids attending a camp last summer.

"It brought the study of earthquakes to life for the kids," Carlucci said. "They were fascinated that 'regular people' — kids like them — could look at earthquake data. So, I'd definitely say it made science much more accessible for them."

Carlucci further noted that, most importantly, the Shakes had sparked students' curiosity.

"It gave us the ability to directly test out their ideas," she said. "Having the Shake here meant that if they had other questions or ideas to test out, we could do that easily."

Carlucci said she separated kids into two groups, allowing one group to stand near the Shake as the other group tried to see what the Shake would

TOP LEFT: Undergraduate student Sarah Sundberg demonstrates a method of teaching folding. LEFT: Dr. Molly Yunker demonstrates how classroom tools can help students understand different types of faults. ABOVE: Dr. Jake Walter demonstrates how a brick and a rubber band can be used to instruct students about earthquakes. BELOW: Workshop participants line up to experience how a kinesthetic activity can be used to demonstrate p- and s-waves in the classroom.

detect, by doing things like walking, talking, or dropping objects. This gave students the experience of being both the experimenter, and the data collector.

"That gave them time for ideas to simmer up to the top, and then we could test them," she said.

"We're very grateful that we have the shake here!"

If you're interested in becoming involved, please contact Dr. Molly Yunker to see if you qualify for a free Raspberry Shake seismograph, provided by the BLOSSM in Oklahoma project.

About the Authors

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.

Molly joined the Oklahoma Geological Survey as the Education and Outreach Coordinator in August, 2017. Her expertise and passion lies at the intersection of geology and education. She earned B.S. and M.S. degrees in Geological Sciences from Case Western Reserve University, where she completed a thesis on the interdiffusion of metals at high pressures and high temperatures. Her Ph.D. is in Science Education from the University of Michigan, where she studied the design and development of science curricula that integrates the outdoor learning environment. Molly spent two years as a Fulbright Scholar and postdoctoral researcher in Israel. She has worked collaboratively with scientists, researchers, educators, and the public to bring earth science concepts to people of all ages, in a variety of contexts. In her free time, Molly loves to be outdoors – visiting new places and eating, canoeing, camping, and hiking. She is a doula, and likes to volunteer, craft, read, garden, and spend time with her husband and son.

OGS hosts technical and core workshop on the STACK Play

Last September, the Oklahoma Geological Survey hosted a workshop focusing on the Sooner Trend Anadarko Basin Canadian and Kingfisher Counties (STACK) Play in Oklahoma. The play was discovered in 2011, and has quickly become one of the hottest resource plays in North America. Despite extensive drilling activity in this play, understanding of the petroleum geology of the area is limited.

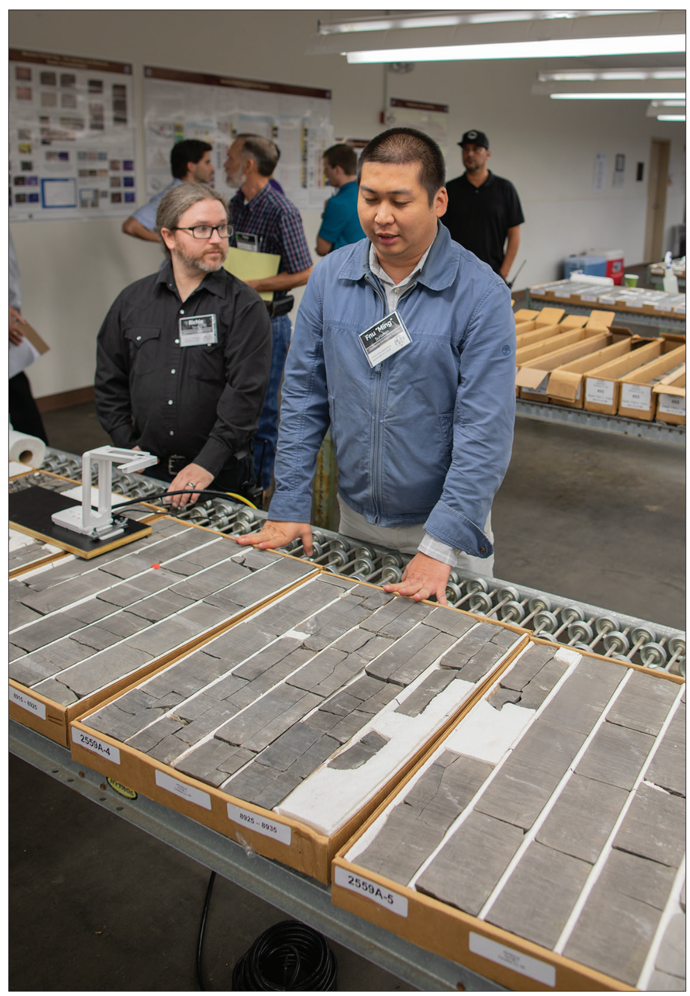
The workshop spanned two days, beginning with a day-long technical workshop held at the Moore-Norman Technology Center, which was attended by over 200 people. The following day, two half-day workshops focusing on core were held at the OGS's Oklahoma Petroleum Information Center (OPIC) in Norman. Each core workshop was attended by around 40 people.

The main objective of the technical workshop was to learn from researchers and operators in the STACK Play, with an emphasis on the Meramec Lime and Woodford Shale. Presentations focused on the depositional system, stratigraphy (biostratigraphy and chemostratigraphy), geochemistry, petrophysics, facies analysis, and fracture characterization that are beneficial for a better understanding of the play and commercial production of hydrocarbons from these low porosity and low permeability reservoirs.

STACK Play technical workshop attendees at the Moore-Norman Technology Center last September. (Photo by Joyce Stiehler.)

ABOVE: Core workshop attendees in the core viewing area at OPIC. **BELOW:** OGS geologist, Ming Suriamin (right), presents at the core workshop. OPIC Manager, Richard Tarver (left), operates the camera allowing all attendees to view core.

The core workshops presented core from several key wells of the Meramec and Woodford Shale in Blaine, Kingfisher, and Canadian Counties. The Meramec cores were viewed to compare and contrast the lithofacies (rock types and their relations) changes from up-dip to down-dip, to examine their characteristics, and to see how the lithofacies correlate to well logs. The Woodford Shale was also displayed to present the characteristics of this unconventional shale reservoir in the subsurface.



David Brown, OGS Associate Director, said that the OGS was uniquely suited for hosting this workshop.

"It's one of the most important plays in the country right now," Brown said, "and it happens to be in our backyard."

The OGS OPIC facility houses core and cuttings from some of the most targeted reservoirs in the STACK play, and hosting a core workshop at OPIC worked as a great complement to the technical sessions held the day before.

"We had our geologists, Ming Suriamin and

OGS made use of a 4K camera to project core images for all attendees to view.

Abbas Seyedolali in particular, perform inch-by-inch analysis of the core and present the results to attendees," Brown said.

Brown said the technical workshop had excellent presentations about the geology of the play but being able to see the rocks was an added value that we were able to provide at our OPIC facility.

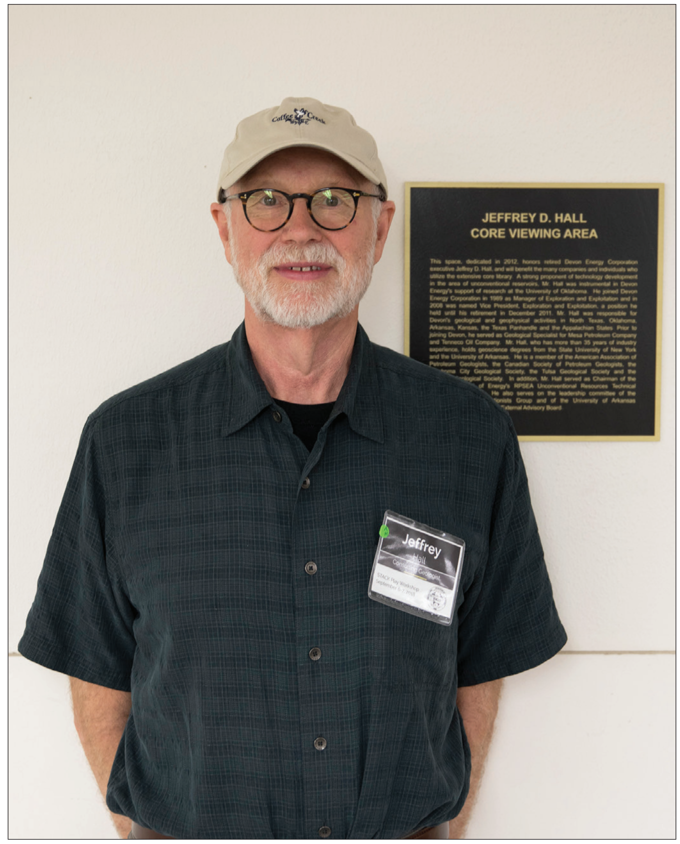
"It's one thing to hear about the science in a PowerPoint presentation, but being able to physically see and touch the rocks and hear the experts as they explain what they are seeing, brings an added dimension to knowledge transfer," Brown said.

Since only a certain number of people can physically gather around a table to view the core, OGS staff made use of a high resolution video camera to make the core viewable to all workshop attendees. Presenters were able to enlarge any features of the core they wished to highlight.

Brown said these workshops were a very effective way to fulfill the OGS mission, and that many attendees were asking when the next workshop would be held. Discussions are taking place about which topic to address next in upcoming workshops.

"We'll do another one as soon as we can," Brown said.

At the workshop, Brown ran into a former



Jeffrey Hall stands next to the plaque commemorating that the Core Viewing Area was named in his honor.

coworker, Jeffrey Hall, from when they both worked at Devon Energy, which led to an interesting revelation.

"I hadn't seen Jeff since I left Devon," Brown said. "I came up to him and said, 'I'm glad to see you in your room.'"

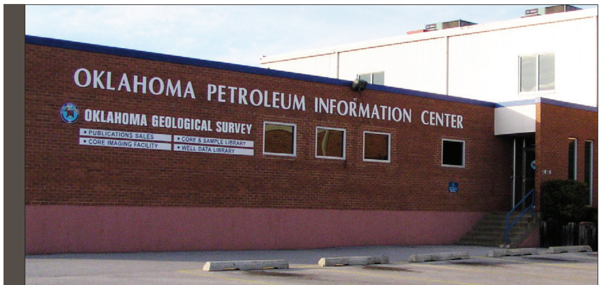
The Jeffrey D. Hall Core Viewing Area had been named after him years ago to recognize him as an integral part of developing the capabilities of the facility. The viewing room was largely built by funds he helped bring into the university.

Hall, however, was not aware that the room was named after him.

"He came back for the workshop because he was very interested in what we were presenting," Brown said. "He wanted to see the core."

When Brown showed him the plaque, he was surprised and humbled by the recognition.

OKLAHOMA PETROLEUM INFORMATION CENTER



"Bringing Together Drill Cores, Well Logs, Well Data, Publications And Services."

Activities and Services

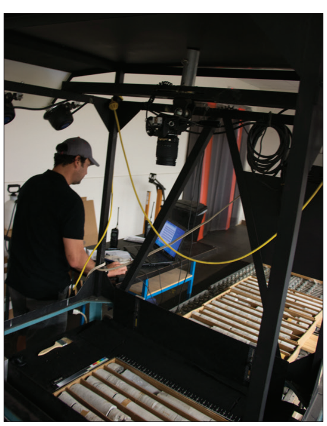
The Oklahoma Geological Survey's Oklahoma Petroleum Information Center (OPIC) is a 192,916 square-foot facility that houses approximately 500,000 boxes of core and cuttings from Oklahoma and elsewhere; an extensive repository of Oklahoma petroleum data; and the Geological Survey's publication sales office.

The OPIC facility is open Monday through Friday from 8AM to 5PM.

Core and Sample Facility

As Oklahoma seeks to maximize the recovery of oil and gas from new, existing, and shut-in wells, these data resources play an ever more important role.

In addition to being a valuable source of information for hydrocarbon exploration and production activities, OPIC's collections are used in many other ways. In particular, the use and appreciation of these materials is increasing because they are a major resource for groundwater studies, land-use change analyses, CO_2 sequestration research, archaeological investigation, and environmental studies.



Fee Schedule

For the most recent fee schedule available for all OPIC services, please go to the OGS website: www.ou.edu/ogs

Well Data Library

The OGS Well Data Library is the State's official repository for full-scale (5 inches to 100 feet) paper logs from more than 450,000 wells, with new logs added daily. In addition to hard copy logs, a backup collection of logs is available on microfiche as well.

Also in the collection are 126,000 strip logs dating from the 1890s which have been recently digitized. In addition, the library maintains a hard copy of 1002A completion reports from 1904 to the 1990s; multiple sets of scout tickets; completion cards for Oklahoma wells; and hard copies of aerial photos dating from 1934-1986 that are filed by county, township and range.

Publication Sales Office

The OGS Publication Sales Office is also located at OPIC. There you can purchase any USGS 7.5 minute quadrangle map of the state, a variety of other USGS maps and all inprint maps and publications produced by the OGS, representing nearly a century's worth of research and mapping.

OGS publications are used by hikers, campers, hunters, school and scout groups, those who enjoy outdoor activities. We have a resource room especially for K-12 teachers, which provides free access to rocks, minerals, fossils, and curricula for classroom use. OPIC is a resource for public officials planning highways and facilities, as well as those engaged in urban planning, water development, alternative energy, and other projects for economic development and civic improvement.

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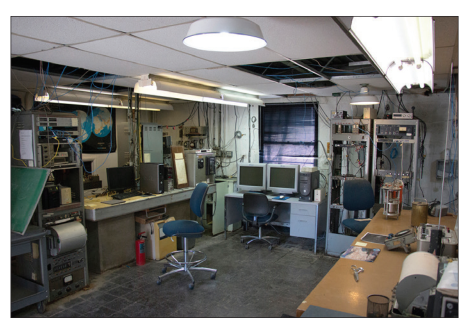
A look back at the rich history of the OGS



During our 111th year, in addition to our technical articles, the Oklahoma Geology Notes will be looking back on significant aspects of OGS history. We'll begin this journey by taking a look at the location where our seismicity research first began: The OGS Geophysical Observatory near Leonard, Oklahoma.