

## OKLAHOMA

**G. R. Keller, Director, State Geologist**  
**Oklahoma Geological Survey**  
**100 E. Boyd, Rm. N-131**  
**Norman, OK 73019**  
**405/325-3031**  
[grkeller@ou.edu](mailto:grkeller@ou.edu)  
[ogs@ou.edu](mailto:ogs@ou.edu)  
[www.ogs.ou.edu](http://www.ogs.ou.edu)

**Mission:** The Oklahoma Geological Survey is a state agency for research and public service located on the Norman Campus of the University of Oklahoma and affiliated with the OU's Mewbourne College of Earth and Energy. The Survey is chartered in the Oklahoma Constitution and is charged with investigating the State's land, water, mineral, and energy resources and disseminating the results of those investigations to promote the wise use of Oklahoma's natural resources consistent with sound environmental practices. The Survey is not a regulatory agency.

Again in 2013 Oklahoma experienced increasing activity and public interest in earthquakes. Seismologists were kept busy locating and assigning magnitudes to the events and responding to questions from the public, other government agencies, the energy industry and, of course, the media. The staff went to great lengths to provide accurate and unbiased scientific findings in an effort to get correct information to the public and counteract the miss-information surrounding earthquakes in Oklahoma.

### Public Service and Outreach

*One of the most important programs at the OGS is public service. It is a daily activity that encompasses everything from phone calls and e-mails to presentations before various scout, educational and civic groups. It could be in the form of a classroom visit, a field trip, or rock identification for someone who walked in unannounced.*

In 2013 the Survey participated in its fifth edition of the *Daily Oklahoman's* Newspapers in Education program that supplies 25 copies of a 16-page workbook, six additional lessons and numerous activities to classrooms across the state. This year's edition was authored by Suneson and the topic was *OKLAHOMA ROCKS! State Parks*. Teachers can sign up for the series free of charge, and the workbooks are supplied in paper copies with additional materials and the teacher guidebook online. In addition, there are six related one-quarter-page lessons that run in the *Daily Oklahoman*, giving wide readership to some interesting and thought-provoking points about the state's geology, its uniqueness, and its impact on the Oklahoma economy.

The Survey builds and maintains rock/mineral kits for Oklahoma earth science teachers. Several kits were sent out to Oklahoma science teachers in 2013, including some who lost classroom material in tornadoes.

The OGS provides speakers and materials for various academic, civic and scout organizations, classrooms, and town-hall meetings, and participates in events such as *Water Day* at the Capitol and *Science Fest* (which is held annually at the Oklahoma City Zoo), and *Science in Action Day* at Sam Noble Oklahoma Museum of Natural History.

Dr. Stanley T. Krukowski worked with the Society of Mining, Metallurgy and Exploration, Inc. serving on the Merit Badge Development and Launch Team to establish the Mining in Society merit badge for the Boy Scouts of America.

Dr. Neil Suneson and Geologist Richard Andrews are again co-teaching a course for the School of Geology & Geophysics at OU. *Geology 4233: Subsurface Methods* is an upper level course emphasizing reservoir engineering, volumetric calculations, unconventional reservoir analyses, interpreting new field studies, well log interpretation, formation evaluation, subsurface mapping. Dr. Suneson also is working with Red Earth Desk and Derrick Club of OKC to create interpretive signs about the geology along Burford Lake Trail in the Wichita Mountains National Wildlife Refuge.

### **Seismic Studies**

*During 2013, earthquakes in Oklahoma again occurred at record levels and consumed a large amount of OGS staff time and effort. Much of the time is spent not only recording and analyzing the latest earthquakes, but evaluating events as they relate to the issue of induced seismicity. While it is well understood that earthquakes can be triggered by fluid injection, it is also well documented that Oklahoma is a known site for active seismicity within the Midcontinent. During 2013, the Survey recorded and located some 2847 local earthquakes here in Oklahoma, with 222 of these reported felt.*

under great scrutiny at the OGS.

During 2013 the OGS brought up to date a number of seismic stations, and in addition installed one semi-continuous station and one permanent station. Eleven OGS temporary seismic stations were operated at 11 different sites, and temporary USGS stations were installed and supported. Seismologist Austin A. Holland also supervised and mentored one undergraduate student and two graduate students, who all received a good deal of experience.

The OGS provides information to federal (USGS, Army Corp of Engineers and EPA), state and local officials about specific earthquakes, earthquake issues, and earthquake hazards, and works closely with the Oklahoma Corporation Commission on the specifics of induced seismicity and drilling activities. In addition, Holland participated in two USGS Powell Center Workgroup meetings on induced seismicity.

Holland and OGS Director G. Randy Keller were involved in countless media interviews locally, nationally, and internationally related to earthquakes in general and induced seismicity and regional seismicity. Holland also presented many talks and town hall meetings on earthquake hazards and recent earthquake activity to different civic groups throughout the state. He initiated many of the meetings and tried when at all possible to address the concerns of citizens and town and city officials. He has made himself and his cell phone number available and answers calls on a 24/7 basis when needed.

In response to concerns that oil and gas industry operations (specifically, injection of drilling waste and production fluids into the ground) may be a cause of earthquakes, the Survey sponsored a workshop on Fluid Injection Induced Seismicity on July 16, 2013. The participants in the workshop represented interested parties such as environmental groups, state agencies, non-governmental organizations, and oil and gas operators. This gathering and exchange of ideas was the first step toward developing a set of recommended best practices to address the issue of induced seismicity. While some earthquakes can be associated with drilling and injection activity, focus also must be on the fact that not all of the increased activity since 2010 can be related to human activities.

Even though the risk of damaging induced earthquakes is small, that risk can be mitigated by appropriate industry practices consistent with the current understanding of the science. Attendees at the workshop discussed a possible set of best practices, and the OGS will take into consideration the comments and concerns expressed and, in continuing consultation with all participants, will ultimately develop a draft set of recommended best practices. These best practices are intended to provide guidelines primarily to the oil and gas industry concerning waste-water disposal wells, but may be applicable in many other cases of fluid injection. Once developed, the draft recommended best practices will be made available for public comment.

## Energy Investigations

Thermal maturity is one of the most important parameters used in the evaluation of gas-shale and shale-oil plays. Vitrinite reflectance (VRo) is a commonly used thermal maturity indicator. Many operators use the vitrinite-reflectance value without knowing what it is or how it is derived. When Brian Cardott joined the Oklahoma Geological Survey in 1981 as an organic petrologist looking at oil and gas source rocks and coal, his first project was to measure the vitrinite reflectance of the Woodford Shale in the Anadarko Basin. Vitrinite, derived from woody organic matter of post-Silurian-age rocks, is used to determine the thermal maturity (from the maximum temperature attained) of the rock ([http://www.searchanddiscovery.com/pdfz/documents/2012/40928cardott/ndx\\_cardott.pdf.html](http://www.searchanddiscovery.com/pdfz/documents/2012/40928cardott/ndx_cardott.pdf.html)).

Thermal maturity, along with the organic matter type (e.g., oil or gas generative) and quantity, is used to estimate the type of hydrocarbon generated. All oil or gas reservoirs require a mature hydrocarbon source rock as the source of produced hydrocarbons. Since the Woodford Shale is an important hydrocarbon source rock and was deposited prior to the Pennsylvanian orogenies, Cardott decided to continue to measure the vitrinite reflectance of the Woodford Shale across the State. Based on this work, the thermal maturity of the Woodford Shale is known in much of the Oklahoma, with the highest recorded vitrinite reflectance in Oklahoma of 6.36% VRo in the Arkoma Basin.

Thermal maturity is one of the key parameters used to evaluate shale as an oil, condensate, or gas reservoir. The Woodford Shale play began with explorationists looking for dry gas (methane) at >1.4% vitrinite reflectance (VRo) in the Arkoma Basin in 2004. The thermal maturity upper limit of the Woodford Shale play is 3% VRo which coincides with the thermal maturity that carbon dioxide is

## Presentations, Publications and Materials

### OGS Workshops and Field Trips

**37<sup>th</sup> Annual Western Interior Coal Forum** – June 4-5, 2013 – 12 Attendees

**Fluid Injection Induced Seismicity Workshop** – July 16, 2013 – 73 Attendees

**Oklahoma Shale Gas & Oil Workshop** – November 20, 2013 – 203 Attendees

**Oklahoma Shale Gas & Oil Field Trip** – November 19, 2013 – 30 Attendees

**Oklahoma Shale Gas & Oil Field Trip** – November 21, 2013 – 34 Attendees

## Basic Geological Studies

**Geothermal: National Geothermal Data System project in cooperation with AASG:** \_\_This is an on-going three year project that began in July 2010 **was completed this year**. The project includes database creation, management, document scanning, and completing many data sheets. Specific data transfers (deliverables) are completed using pre-arranged templates that are extremely elaborate and require constant revisions.

**Helium:** Dr. Julie Chang has been investigating helium and has compiled a bibliography of helium references for Oklahoma and other localities, and produced a map in ArcMap 10.0 of helium contents for natural gas wells in Oklahoma and surrounding states. She is also writing articles about helium in Oklahoma for the Oklahoma City Geological Society's *Shale Shaker* and *Oklahoma Geology Notes*.

**Field Trips:** Members of the Survey staff also planned and led many field trips throughout the state in 2013. Some are associated with meetings and workshops while others are for various professional or educational groups. An example of the more unusual topics was cement company exploration efforts for raw materials in Oklahoma and north Texas.

**Mining and Minerals:** Dr. Krukowski keeps track of Oklahoma's mineral resources and works with various professional groups and companies within the state. His research projects include: contributing to the Directory of Oklahoma Mines; as well as industrial minerals utilization by Native Americans.

**Other:** Dr. Keller, Kevin Crain and Vikram Jayaram continue to study the deep structure of Oklahoma and surrounding areas for their 3-D geophysical models. This is part of an NSF funded project on the mid-continent rift.

The OGS is working on new integrated studies made along the Ouachita orogenic belt. This work is based on industry 3-D seismic data from that area.

Another very useful project taken on by Geologist Brittany Pritchett involves going through field guides and picking out the locations of the stops, cataloging what the stops were viewing (formations, uncommon minerals, fossils, etc.), then putting this information in Google Earth. The ultimate goal is to create an interactive map on the OGS website where one could search by field guide and see the location of the stops and what featured or search by geological formation and see every field guide/stop that includes that particular formation and locating it.

Pritchett also is updating the oil and gas field map (GM 36) that was published 10 years ago, and addressing the problems of part of the Pennsylvanian stratigraphy (Krebs through Skiatook Group) in Oklahoma. She is trying to reconcile rock formations called different names or used as Group, Formation, or Member interchangeably. She also spends time working with graduate students in the Devon X-Ray Diffraction Lab for OU's Conoco-Phillips School of Geology and Geophysics.

## Oklahoma Petroleum Information Center: OPIC

Along with many patrons from the energy industry, OPIC is a 200,000 sq. ft. facility used by many individuals and groups seeking a variety of information. Labs are held there for OU geology students and groups of teachers come for tours and special teaching sessions. Individuals and many associated with state and federal agencies also make use of the massive core and sample collections, paper data records, and aerial photos housed here.

The number of boxes of cores pulled increased from 12,036 in 2011 to 13,412 in 2012, and 15,758 in 2013. Also in 2013:

Donations Received and Logged In;

- Core: 45 wells /912 boxes
- Cuttings: 700 wells/1754 boxes
- Shawnee: (log in only) 293 wells/488 boxes

## Mapping and Cartography

**The STATEMAP program**, with Drs. Tom Stanley and Julie Chang, is currently in its 17<sup>th</sup> year. To date, more than 42 detailed 7.5' geologic maps at a scale of 1:24,000, and 16 reconnaissance maps at 1:100,000, are complete and available on the website, and in hard copy and digital format upon request.

Now that mapping of the Tulsa Metro Area is completed, detailed, 1:24,000 mapping has shifted focus to mapping of the Vanoss Quadrangle of Ada Area project.

## AASG REPORT 2013

The northwest to southeast sweep across the state with the reconnaissance-mapping program continues. The conjoined, Tishomingo-Sherman 1-degree sheet should be available to the public later in the year.

Dr. Stanley also serves as an Adjunct Professor for the ConocoPhillips School of Geology and Geophysics, and teaches the department's Geology Field program in Canon City, Colorado.