Increased seismicity in Kansas
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Abstract
Most people, including those who live there, regard Kansas as a seismically quiet place. Until a couple of years ago, hardly anyone I met from Kansas had felt an earthquake that had originated within the state. That all changed about 18 months ago. In the fall of 2013, the state experienced several events, reported by the U. S. Geological Survey (USGS) and Oklahoma Geological Survey (OGS), including a magnitude 4.2 earthquake in December 2013. In 2014, the USGS National Earthquake Information Center reported more than 100 events with epicenters inside Kansas. The largest was a magnitude 4.9 in November 2014.

Introduction
Prior to 2013, Kansas seldom had more than one or two felt earthquakes in a given year. However, 2014 was a particularly active year for earthquakes in Kansas, including events greater than magnitude 4, as shown in Figure 1. Most of the activity has been in the south-central part of Kansas (Figure 2), in Harper and Sumner counties, near the Oklahoma border (detailed in Figure 3).

At the same time, some of the larger events in north-central Oklahoma have been felt in Kansas as well. The year 2015 started out with seismic activity in the same area, as demonstrated in Figure 4. This seismic activity is in marked contrast to previously recorded earthquakes, as seen in Table 1.

There appears to be a correlation, in time and location, between the seismicity and large-volume saltwater-injection wells from oil and gas production. Certainly the area where the earthquakes have occurred correlates with increased oil production and horizontal drilling, part of the Mississippian limestone play that moved up from Oklahoma into southern Kansas in the past three to four years. That activity saw an increase in large-capacity saltwater-disposal wells and disposal volumes in the area (Figure 5).

Although we all know that correlation does not equal causation, the dramatic increase in seismic activity, along with its location and timing, certainly makes induced seismicity a strong possibility.

Actions in response to Kansas earthquakes
Dealing with increased seismicity poses special challenges in a place such as Kansas that is relatively unaccustomed to earthquakes and is relatively underinstrumented in terms of their measurement. At the beginning of this increased seismic activity, there were only two seismograph stations in the state, both operated by the USGS and both a significant distance from most of the earthquakes. Thus, the state depended on the USGS and OGS for data about events in Kansas.

The Kansas response began in the fall of 2013 when Governor Sam Brownback convened a meeting of the Kansas Geological Survey (KGS), the Kansas Department of Health and Environment (KDHE), and the Kansas Corporation Commission (KCC). The latter two agencies regulate Class I and Class II underground injection wells in Kansas. In February 2014, Brownback formalized this response by appointing the three agencies to an induced-seismicity task force and

Figure 1. Earthquake activity in Kansas by month and magnitude range for (a) 2013, (b) 2014, and (c) 2015. Earthquake totals for April 2015 reflect only events recorded through 17 April.
charged them with making recommendations for dealing with seismicity.

This task force met repeatedly, drafted a response plan, held a public meeting in Wichita, Kansas, that was attended by nearly 100 people, revised that plan, asked for another round of public comment, and then submitted the plan to the governor’s office in late September 2014. This report was modified slightly on 21 January 2015 (Kansas Seismic Action Plan, rev. 2015).

The plan called for enhanced monitoring, with both a permanent state-operated network and the development of a temporary array that could be located in areas of activity. The plan also proposed a seismic-activity scoring formula to guide agency response. That formula included magnitude, number of clustered events, proximity to structures, and other factors in developing a threshold score. Events that exceeded a threshold score would cause the KCC and KDHE to gather information on disposal-well volumes and pressures in proximity to the epicenter. This scoring method was an attempt to create a quantifiable method of differentiating induced from natural seismicity and an attempt to take into account more factors than simple magnitude when forming a response.

On 2 October 2014, six days after the task force submitted its report to the governor, a 4.3 earthquake occurred in Harper County, Kansas. The task force and the governor met with the Harper County Commission to discuss the activity and the state’s response. Although the commissioners expressed concern about the earthquakes, they also stated their support for the recent oil and gas activity in the area. Brownback promised regular communication and funding for enhanced monitoring.

In November 2014, a 4.9 event occurred in Sumner County, Kansas (Figure 6), the largest earthquake ever recorded by instrumentation in the state (an earthquake of fairly similar size occurred in northeastern Kansas in 1867, obviously before the days of instrumentation; it generally has been rated a VII on the Modified Mercali [MM] Intensity Scale). The 2014 earthquake did minor damage and was felt far outside the state’s borders.

During the past year, the USGS has installed a temporary network over the top of the activity in Harper and Sumner counties. KGS has installed seven stations over a somewhat larger geographic area, to pinpoint depths and epicenters, to guide installation of the permanent network, to help guide future responses (scientific and regulatory), and to gather background data in areas of potential earthquake activity in the future. These new KGS stations, combined with existing stations, provide better coverage over the state (Figure 7), which can be used to make regulatory decisions, constrain locations for approving new permits, and define zones of increased risk.

Table 1. Statistics for earthquakes in Kansas detected by the Kansas-Nebraska seismic network (1977–1989) and the U. S. Geological Survey (1990 to the present).

<table>
<thead>
<tr>
<th>Time period</th>
<th>Statewide</th>
<th>Harper and Sumner counties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Magnitude 2.5 earthquakes</td>
<td>Magnitude 2.0 earthquakes</td>
</tr>
<tr>
<td>1977 through 2012</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>2013 to present</td>
<td>115</td>
<td>138</td>
</tr>
</tbody>
</table>

Figure 2. The increase in earthquake activity in Kansas in 2014 has occurred southwest of Wichita. Map from Kansas Geological Survey. Earthquake data from Oklahoma Geological Survey and U. S. Geological Survey.


Table 1. Statistics for earthquakes in Kansas detected by the Kansas-Nebraska seismic network (1977–1989) and the U. S. Geological Survey (1990 to the present).
Discussion

What have we learned from all this? First, determining the cause of the events — and thus an appropriate response — is difficult because of the lack of instrumentation and the relatively poor understanding of the mechanisms behind these earthquakes. The installation of seismographs is improving the ability to locate the events almost every day, but we still struggle with lack of 3D seismic data that could be used to locate faults in the area. In some areas, 3D seismic data are not available. In other locations, the data are proprietary. Similarly, disposal data previously were available only annually. The lack of disposal data, 3D seismic data, and earthquake data combined makes this a challenge.

Second, we have had incredible assistance from colleagues, especially those in Oklahoma who have gone through much more of this and for longer than Kansas has. They have been unfailingly helpful at a time when they have their own issues to deal with. Because so many of these events occur near the Kansas-Oklahoma line, it is particularly important that we compare notes regularly, and we have. We also have borrowed some equipment from the University of Missouri. It has been good to watch the geoscience, regulatory, and academic communities come together to try to understand and address this issue.

Third, and perhaps most challenging, has been the public component of all this. Some segments of the public were understandably upset by the earthquake activity. They wanted action taken, even when it was not always clear what action would be effective or appropriate. On the other hand, many members of the public did not want anything done that might discourage oil exploration, drilling, and production in the area.

It clearly is not possible to satisfy everyone. However, it is possible to talk with various groups, and a clear lesson is the importance of regular communication with people in the affected areas. Although we have not held any large town-hall meetings, we have met regularly with the county commissions in those areas. Making the effort to travel to their meetings, even when we did not necessarily have anything new to report, helped to develop a relationship that has allowed open and honest interaction, without being adversarial. In addition, speaking to groups in Wichita, the nearest large city, has helped.

Perhaps an even more difficult component of the public part of this has been dealing with the media. Even in these days of social media, traditional mass-media outlets are still terrifically influential in terms of providing information. Much of the media coverage has been responsible and fair. Reporters have worked hard to understand this complex issue and get the facts right. However, other coverage has been less successful.

A constant drumbeat has been the possible connection between hydraulic fracturing (fracking) and these earthquakes. Although a small number of earthquakes in other states has been directly attributable to hydraulic fracturing, we have been clear that the correlation in Kansas is between saltwater disposal and earthquakes.

Nevertheless, some newspaper and wire-service coverage has insisted that fracking causes our earthquakes. They either cannot or will not make the distinction between hydraulic fracturing as part of the drilling process and saltwater disposal as part of the production process. The first step in dealing with a problem is, it seems to me, defining the problem appropriately, but that is not how some reporters see it.

We have also reported regularly to our legislators. Updating them on the activity and how we are responding is important, especially for legislators who represent the affected areas. Much of that reporting is done in the highly visible forum of legislative hearings. In my experience, the more regularly legislators are updated, the more opportunities they have to express their concerns and get their questions answered, the better the result.
Conclusions

Dealing with this has been interesting scientifically but sometimes frustrating and stressful. I do not think any of us expected or aspired to such a visible and controversial role, but that is where we are and where we apparently will be for some time. Even though oil prices and drilling are down right now, we have no reason to believe that this issue will resolve itself permanently or go away any time soon. One take-home lesson may be that the public component is impossible to avoid and probably is one we need to embrace if we are to deal with this issue successfully.

Acknowledgments

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Reference


Figure 7. Proposed permanent earthquake-monitoring network for Kansas.