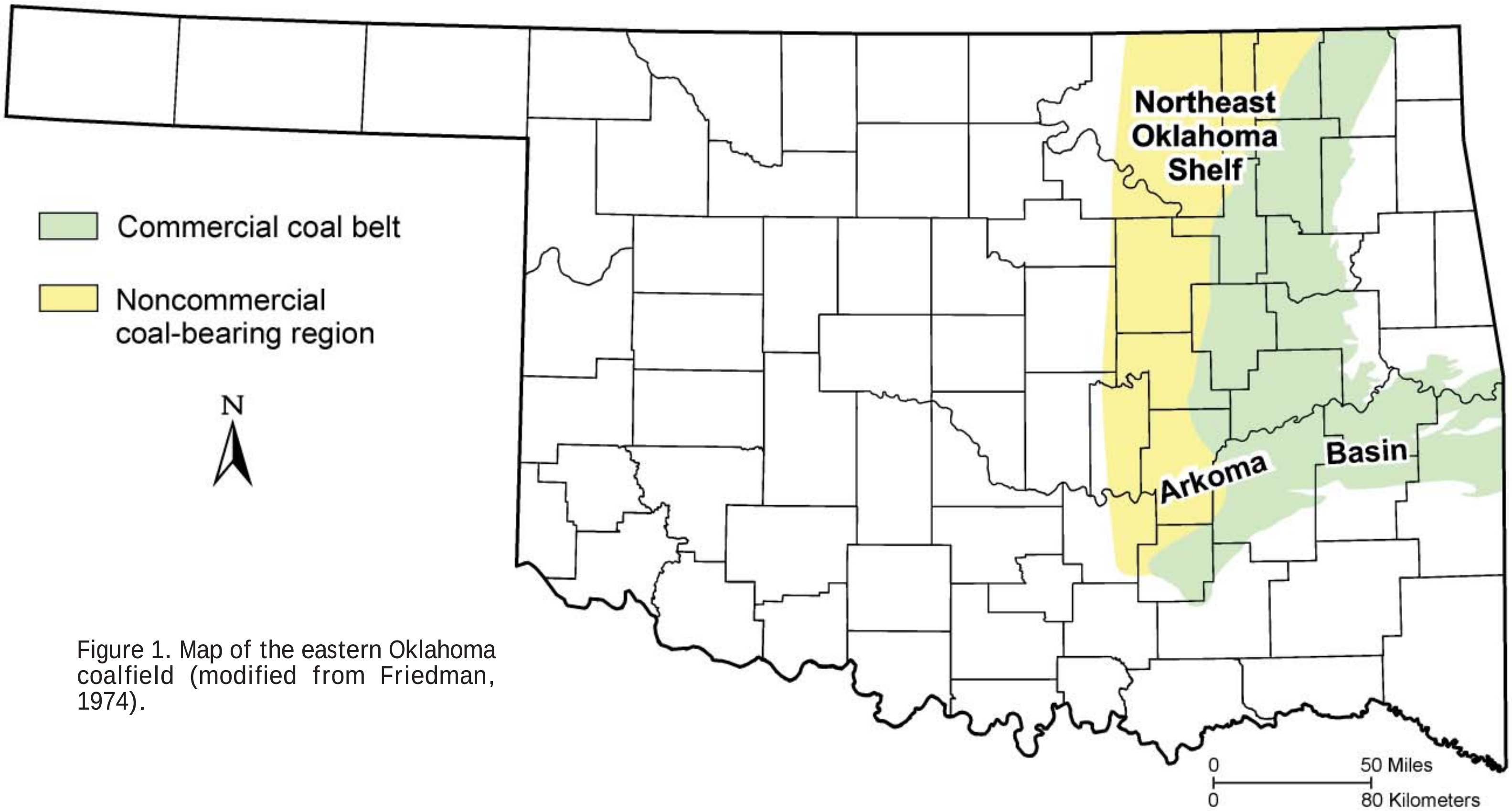

Figure 1. Map of the eastern Oklahoma coalfield (modified from Friedman, 1974).

Issues Related to Oklahoma Coalbed-Methane Activity, 1988–2008

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INTRODUCTION

Numerous studies and tax incentives led to the development of coalbed methane (CBM) in Oklahoma beginning in 1988. Studies by the U.S. Bureau of Mines from 1964 to 1980, primarily for underground-coal-mine safety (summarized in Deul and Kim, 1988), and later by the Gas Research Institute (numerous reports from 1979 to 2000) led to the development of CBM as an energy resource. Commercial production of CBM began in the San Juan Basin of Colorado and New Mexico in 1977 and the Black Warrior Basin of Alabama in 1980. The United States Internal Revenue Service (IRS) § 29 income tax credit further stimulated interest in CBM (Phase I from 1980 through 1992, Phase II from 1993 through 2002; summarized in Sanderson and Berggren, 1998). Long before the first CBM well was drilled in Oklahoma, Friedman (1982) described the potential for CBM in rural eastern Oklahoma.

Friedman (1974) divided the eastern Oklahoma coalfield into the commercial coal belt (area known to contain coal beds of commercial value for coal mining) and the noncommercial coal-bearing region (area containing coal beds too thin or deep for mining; **Figure 1**). There are CBM wells in both areas. The coalfield is further divided into the northeast Oklahoma shelf ("shelf") and the Arkoma Basin ("basin"). Coal beds on the shelf strike north-northeast and dip 2°–3° to the west; CBM wells occur west of the outcrop belt. The coal beds in the basin are highly folded and faulted (Cardott, 2002).

The first CBM wells in eastern Oklahoma were drilled in 1988 to the Hartshorne coal (middle Pennsylvanian) in Haskell County. From 1988

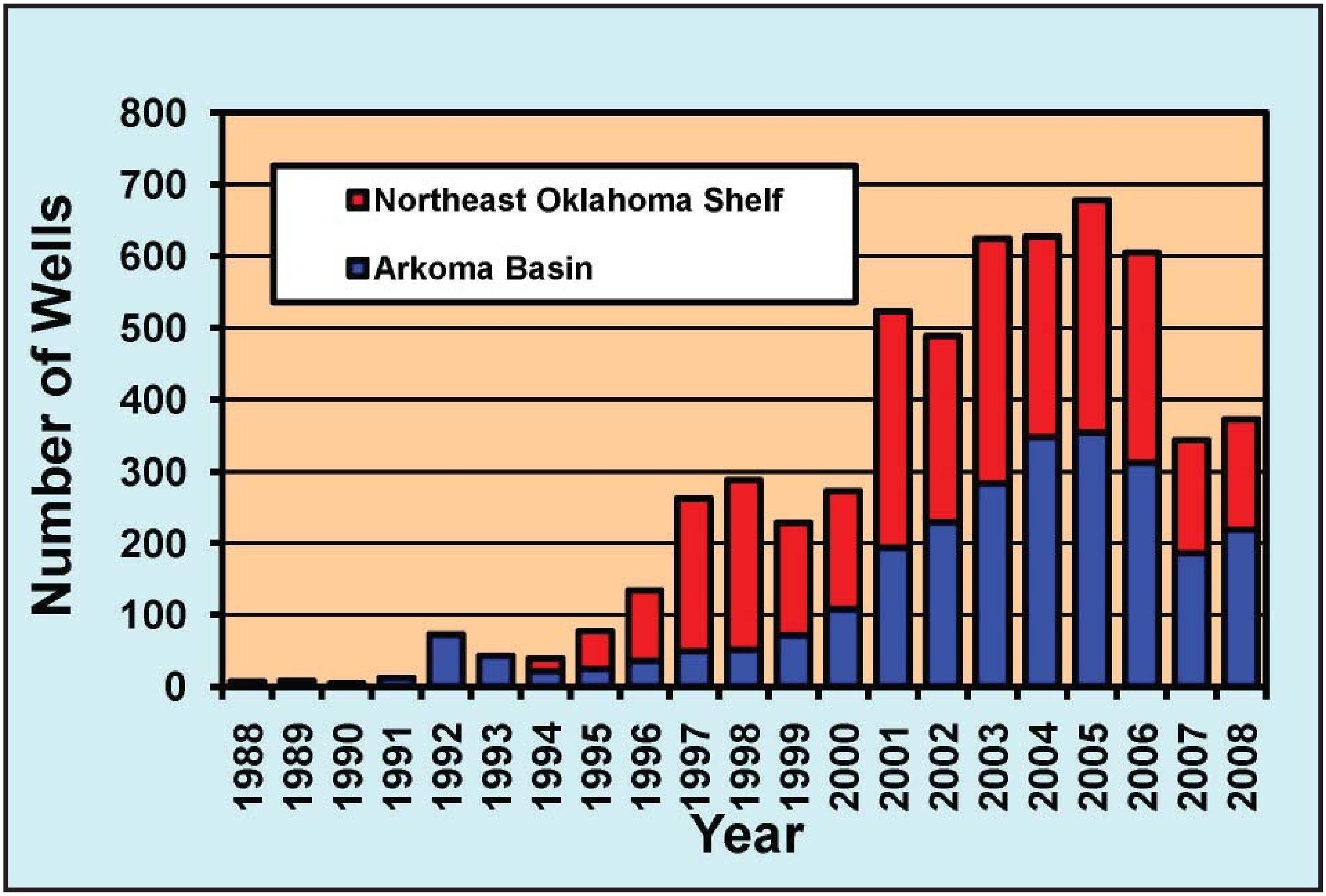


Figure 2. Histogram showing numbers of Oklahoma coalbed-methane (CBM) well completions, 1988–2008.

through 2008, 5,707 gas wells were completed to coal beds in eastern Oklahoma (**Figure 2**). The peak of 73 wells drilled in the basin during 1992 occurred at the end of the first phase of the § 29 tax credit. Drilling expanded to the shelf in 1994 (**Figure 3**), in part to take advantage of the tax credit, exemplified by the large number of recompleted wells (discussed below). The highest number of CBM wells completed in Oklahoma in a single year was 678 wells in 2005.

Several issues over the years have influenced the development and reporting of CBM wells in Oklahoma. These issues, discussed below, impacted what wells to include in a CBM completions database (available on the Oklahoma Geological Survey website, http://www.ogs.ou.edu/coaldb.php) and how to compare and evaluate them.

ISSUES IN OKLAHOMA CBM

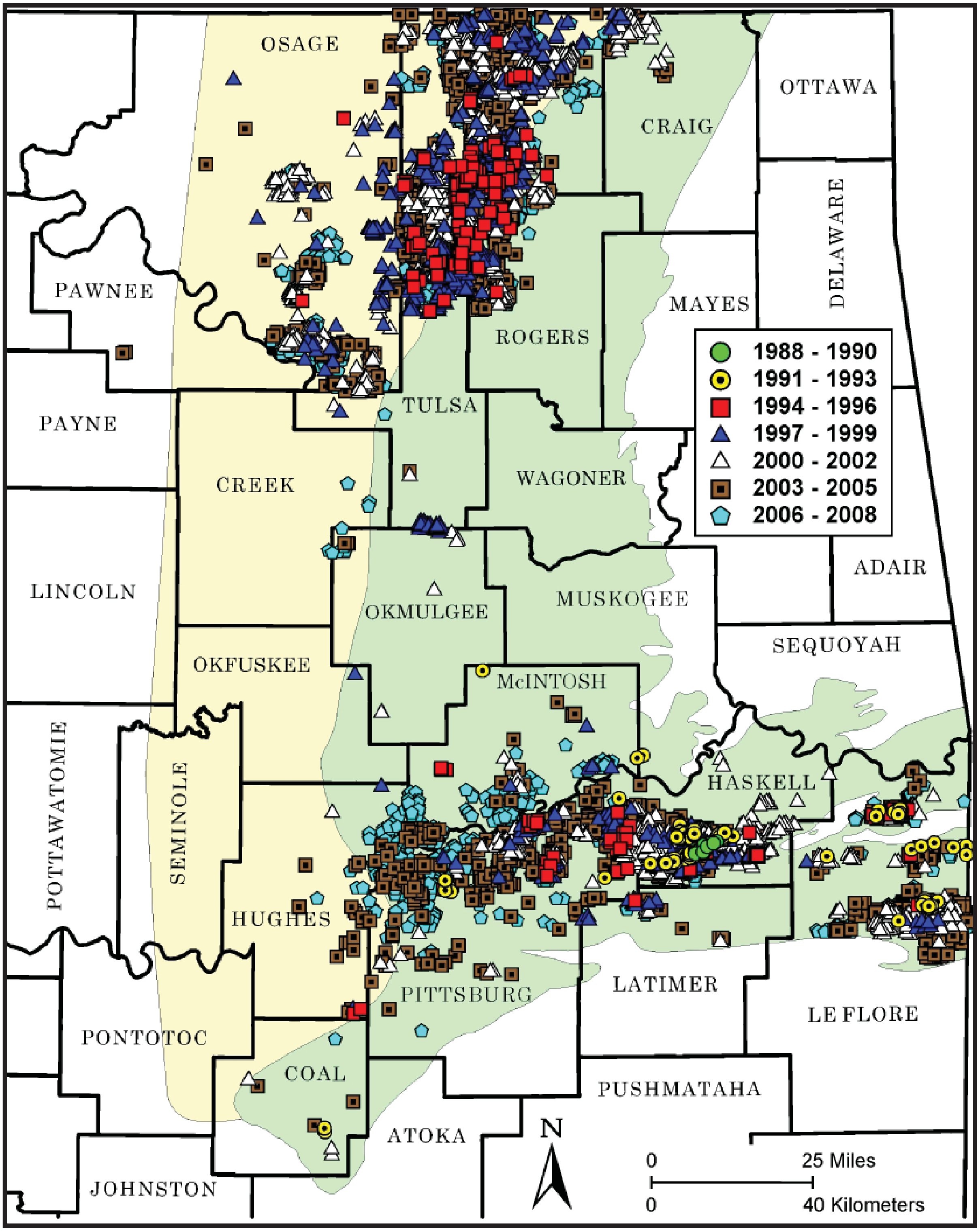
Recompletions

Beginning in 1991, several pre-existing petroleum wells in the basin were recompleted as CBM wells. Recompleting wells was a pivotal part of the second phase of the § 29 tax credit (1993–2002). This phase allowed for recompleting wells drilled from 1980 through 1992, provided that they were not deepened. Recompleting eligible wells to coal beds stimulated interest in drilling for CBM on the shelf beginning in 1994. Through 2008, 738 (13%) of 5,707 Oklahoma CBM wells were recompletions; however, most (687) recompleted wells were on the shelf (**Figure 4**).

CBM Wells with Noncoal Contributions

Nelson and Pratt (2001) recognized that hydrocarbon-source-rock shales, with densities >1.75 g/cm^3, can contribute significant amounts of methane to CBM wells. Without restrictions such as those imposed

Figure 3.
Map showing coalbed-methane (CBM) well completions in Oklahoma by year.



for the tax credit or state limitations (e.g., sharing allowable, separate sources of supply), operators are permitted to produce as much methane from a well as possible with no requirement to limit the production strictly to CBM. Beginning in 1992, some Oklahoma CBM wells included perforations of noncoal lithologies, including sandstone (e.g., Bartlesville, Burgess, Cleveland, Peru, Red Fork, Skinner, and Tucker/Cushing), limestone (e.g., Big Lime, Oswego, Pink Lime, and Verdigris), and shale (e.g., Little Osage, Nuyaka, Oakley, and Summit). Only wells with noncoal perforations as a minor component were included in the CBM completions database. CBM wells with perforations in thin noncoal lithologies represent 330 (6%) of a total 5,707 (**Figure 5**).

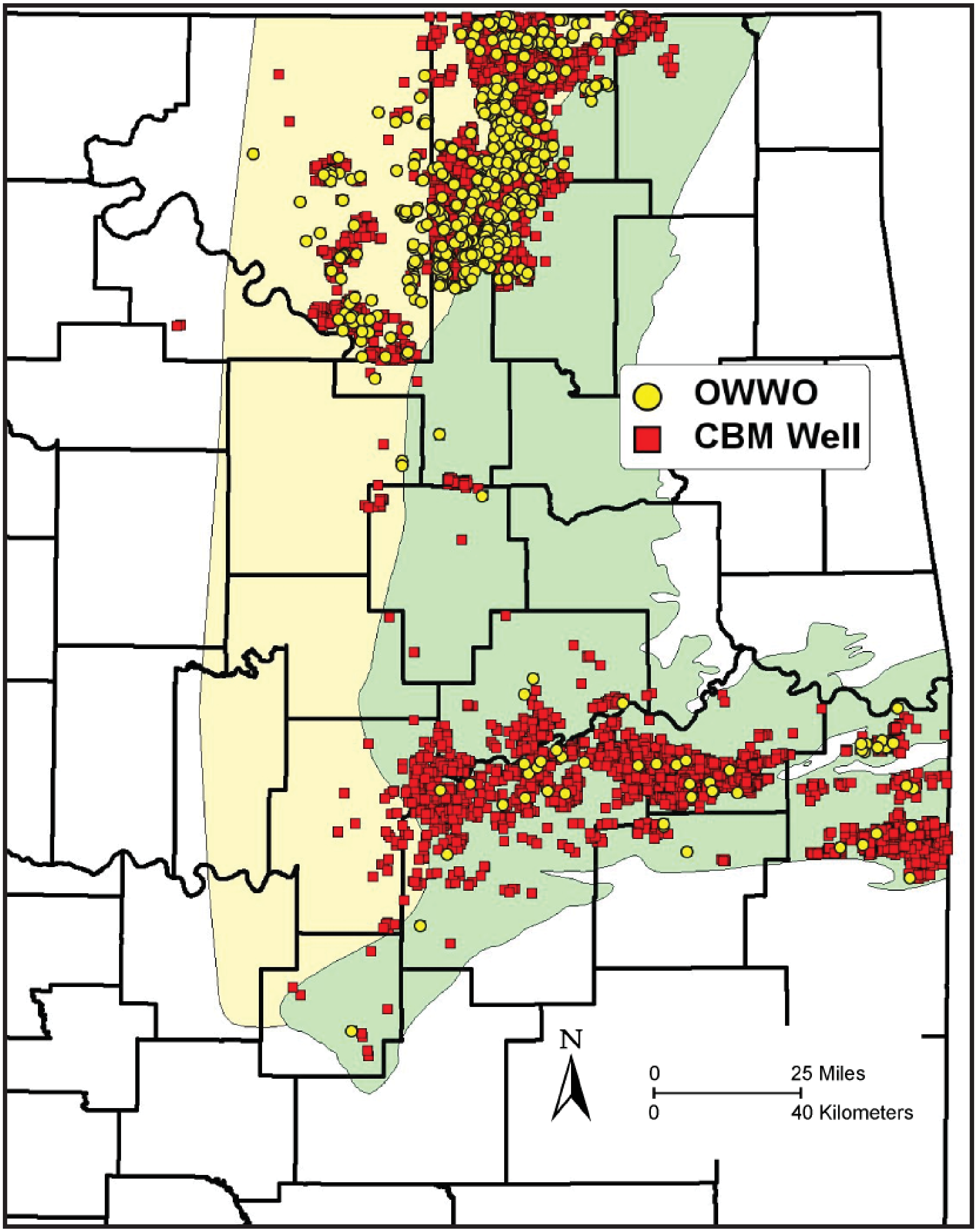
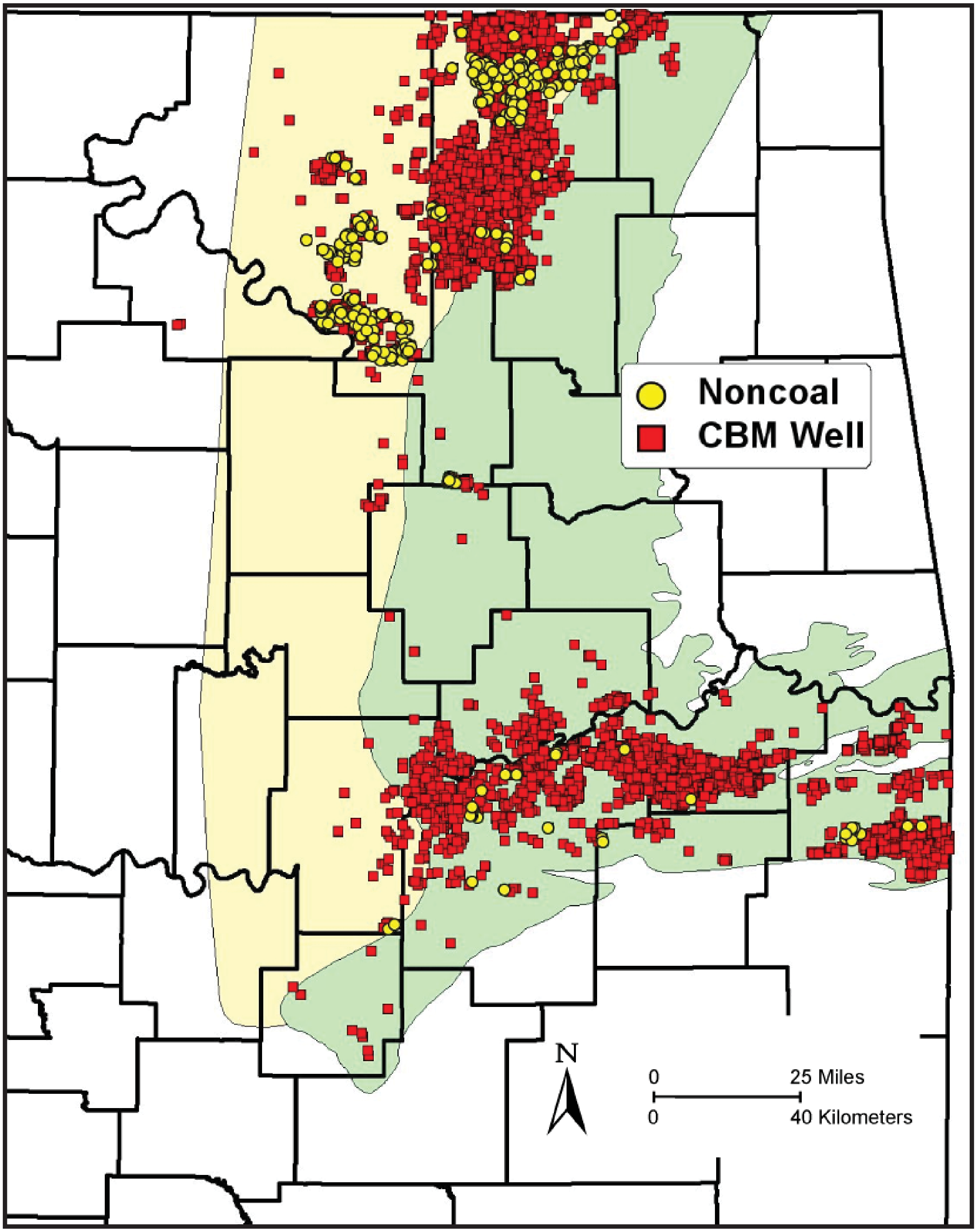


Figure 4. Map showing recompletions (old-well work-over, OWWO) as coalbed-methane (CBM) wells in Oklahoma (1991–2008).

Mulky Coal

Hemish (1986) reported a thin (<10 in.) coal above the Breezy Hill Limestone as the Mulky coal (top of the Senora Formation) in northwest Craig County (T. 28 N., R. 19 E.; chemistry is not available to verify coal grade). Hemish (2002, p. 11) used a “Mulky marker” to indicate the Mulky coal interval, stating that, “If present, the Mulky coal occurs at the base of the Excello Shale, but it cannot be identified separately on the geophysical logs.” A cross section from Crawford County, Kansas, to Craig County, Oklahoma, in Hemish (1986, figure 13) illustrated the Mulky coal pinching out to the south. **Figure 6** is a photograph of a coal-mine highwall in Nowata County (Sec. 32, T. 25 N., R. 17 E.) showing the Excello Shale in contact with the Breezy Hill Limestone with

Figure 5. Map showing coalbed-methane (CBM) wells with perforations in noncoal lithologies (1992–2008).



the Mulky coal absent.

Cassidy (1968, Figure 1) showed the Excello Shale outcrop striking north-northeast in northeast Oklahoma and the approximate southern limit of the shale in southern Tulsa County. The 506 Mulky-only wells (1994–2008) in **Figure 7**, extending to the southern limit of the Excello Shale, are more likely perforated in and producing gas from the Excello Shale.

Commingled Coals

There are more than 40 named and unnamed coal beds in the northeast Oklahoma shelf (Hemish, 1988). Most coal beds are <2 ft thick. The 15 middle Pennsylvanian coal beds in CBM wells on the shelf are, from

Figure 6. Photograph of Excello Shale (above) and Breezy Hill Limestone contact (white line) in surface coal-mine highwall in Nowata County.

oldest to youngest: Riverton, Rowe, Drywood, Bluejacket, Wainwright, Weir-Pittsburg, Tebo, Mineral, Fleming, Croweburg, Bevier, Iron Post, Mulky, Lexington, and Dawson. From 1995 through 2008, 824 CBM wells on the shelf commingled 2 to 9 coal beds per well. Only the shallowest coal bed represents the location of a commingled well plotted in **Figure 8**, which shows all CBM wells on the shelf.

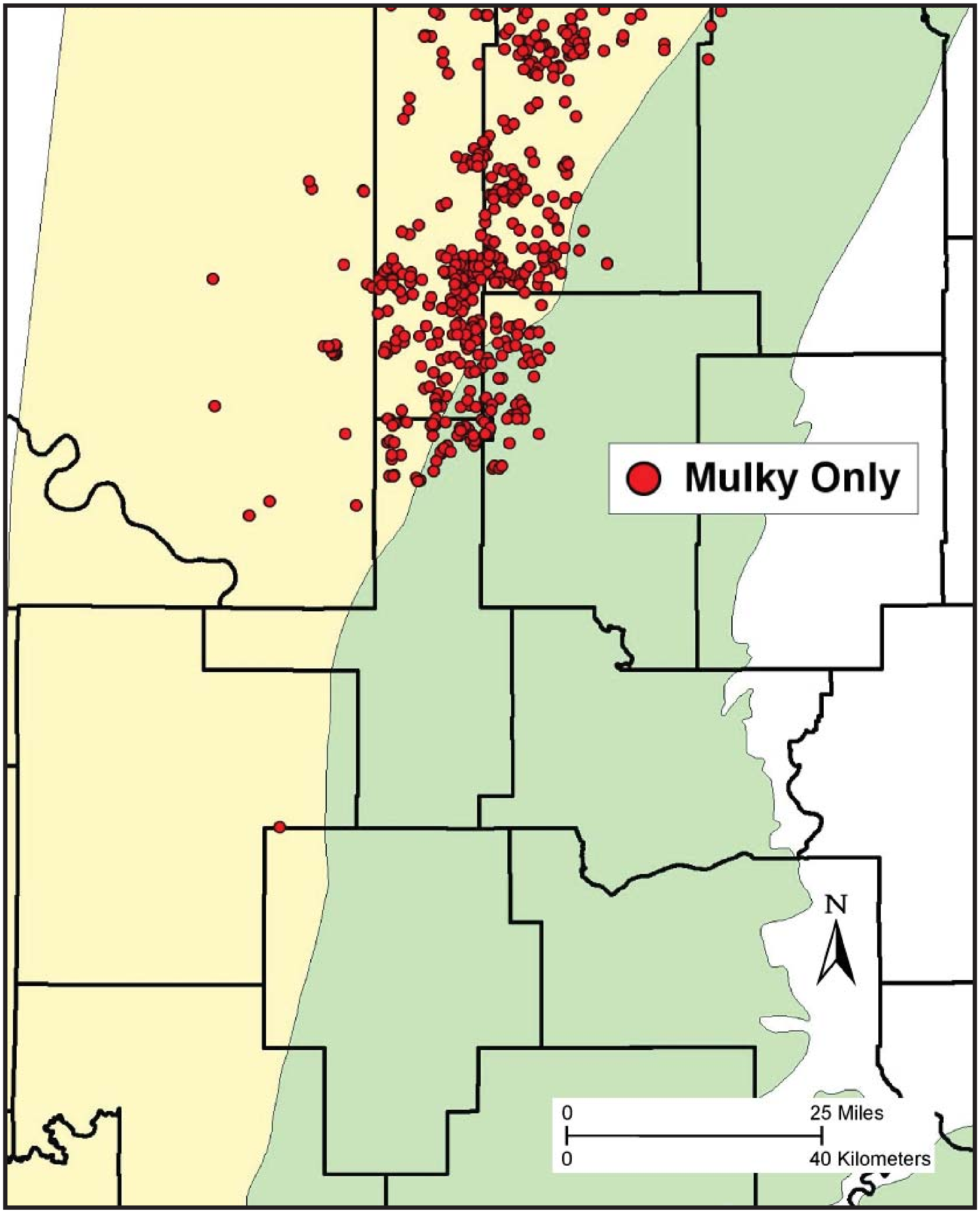
Horizontal CBM

Some of the 6 horizontal CBM wells in the basin drilled during 1998 encountered problems staying in the coal. Beginning in 1999, advances in horizontal drilling, such as measurement while drilling using a gamma sensor, gave drillers the tools to keep the lateral within coal beds >3 ft thick. Almost all (1,565) of the 1,600 horizontal CBM wells from 1998 through 2008 are in the basin. The success of horizontal CBM wells sparked an increase in drilling them over vertical wells. During 2005, 333 (94%) of the 353 CBM wells drilled in the basin were horizontal wells (**Figure 9**). Beginning in 2004, 27 horizontal and 8 directional CBM wells were drilled on the shelf (**Figure 10**).

Gas Fields

Coals are recognized as continuous accumulations. Schmoker (1999, p. 1) defined **continuous accumulations** as ***"petroleum accumulations that have large spatial dimensions and which lack well-defined down-dip petroleum/water contacts."*** As such, CBM wells extend beyond conventional gas-field boundaries (e.g., Boyd, 2002). Rather than expanding the established gas-field boundaries to incorporate CBM wells, the Oklahoma Corporation Commission (OCC) began in 2001 to use county names in assigning CBM gas fields

Figure 7. Map showing Mulky-only coalbed-methane (CBM) wells in Oklahoma (1994–2008).



(e.g., Le Flore County CBM Gas Area). However, conventional gas-field names are used in the field-name column in the CBM completions database when a CBM well occurs within an established gas-field boundary.

"Pennsylvanian" CBM

Beginning in 2005, the OCC passed spacing orders granting permission to report commingled CBM wells on the shelf as "Pennsylvanian" CBM wells (representing 248 of the 5,707 wells in **Figure 11**). This ruling may have decreased the amount of paperwork that companies need to file, but it does not provide the necessary details of what coal beds were perforated or how productive they are.

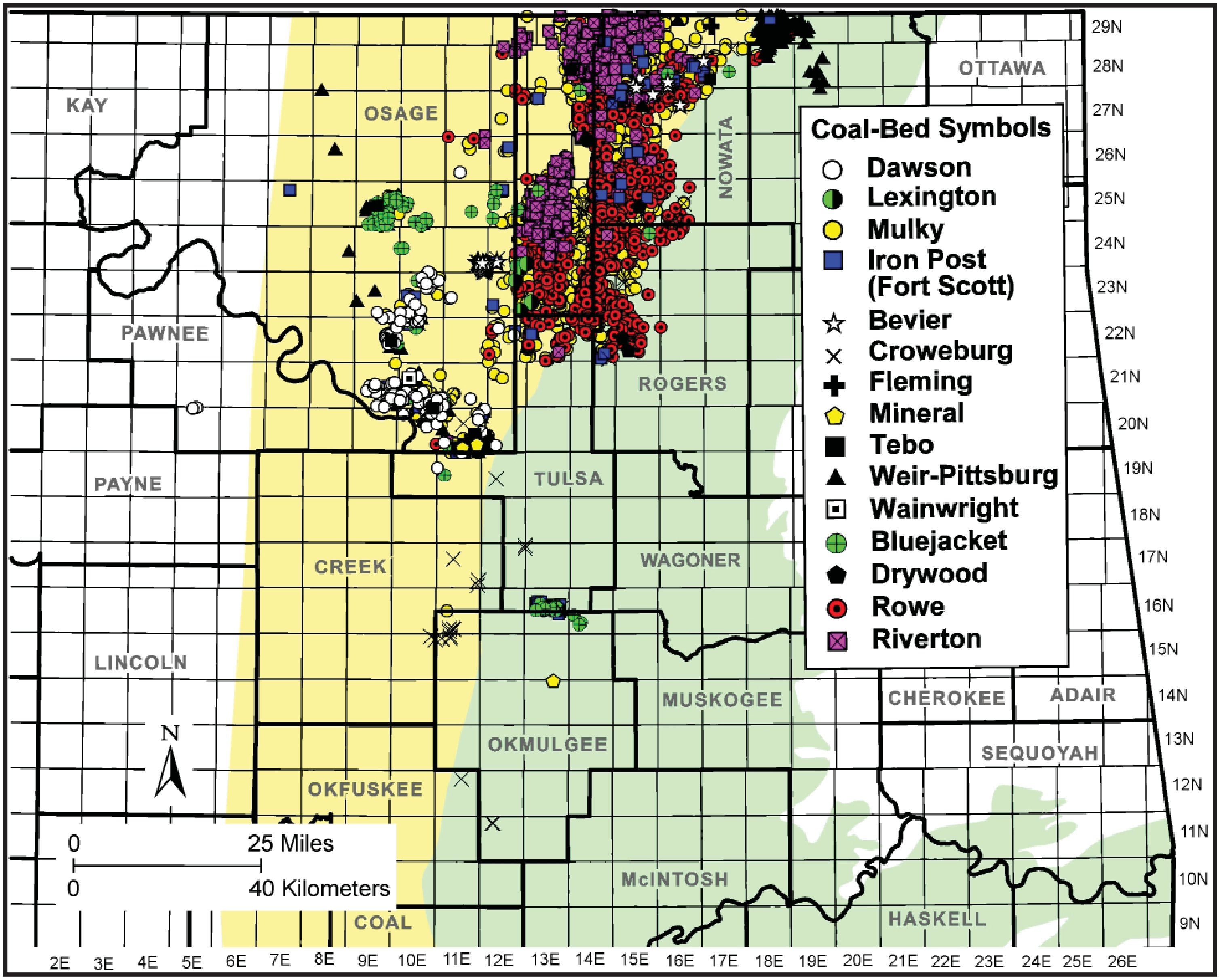


Figure 8. Map showing coalbed-methane (CBM) wells on northeast Oklahoma shelf (1994–2008). Only the shallowest coal bed is used to represent commingled CBM wells.

IMPLICATIONS AND CONCLUSIONS

From 1988 through 2008, 5,707 gas wells were completed to coal beds in the eastern Oklahoma coalfield. Several issues over these years have influenced the development and reporting of coalbed methane (CBM) wells in Oklahoma. The issues impacted what wells to include in a CBM completions database, and how they would be compared and evaluated.

Beginning in 1991 in the Arkoma basin ("basin") and beginning in 1994 on the northeast Oklahoma shelf ("shelf"), pre-existing petroleum wells were recompleted as CBM wells. These 738 CBM wells produced significant amounts of gas; however, they present a problem when summarizing gas production from them. When summarizing CBM production, either recompleted wells must be excluded so that gas produced from noncoal formations is not arbitrarily included, or gas produced from each recompleted well must be added separately, starting with the date of the recompletion as a CBM well. The former method was used in the past (Cardott, 2005) resulting in a conservative estimate of CBM-produced gas (cumulative production of 125 Bcf gas from 1,898 CBM wells on the shelf and 372 Bcf gas from 2,418 CBM wells in the basin from 1988 through 2008).

Beginning in 1992, some Oklahoma CBM wells have additional perforations in thin noncoal lithologies (sandstone, limestone, and shale). Because CBM is believed to contribute most of the produced gas, 330

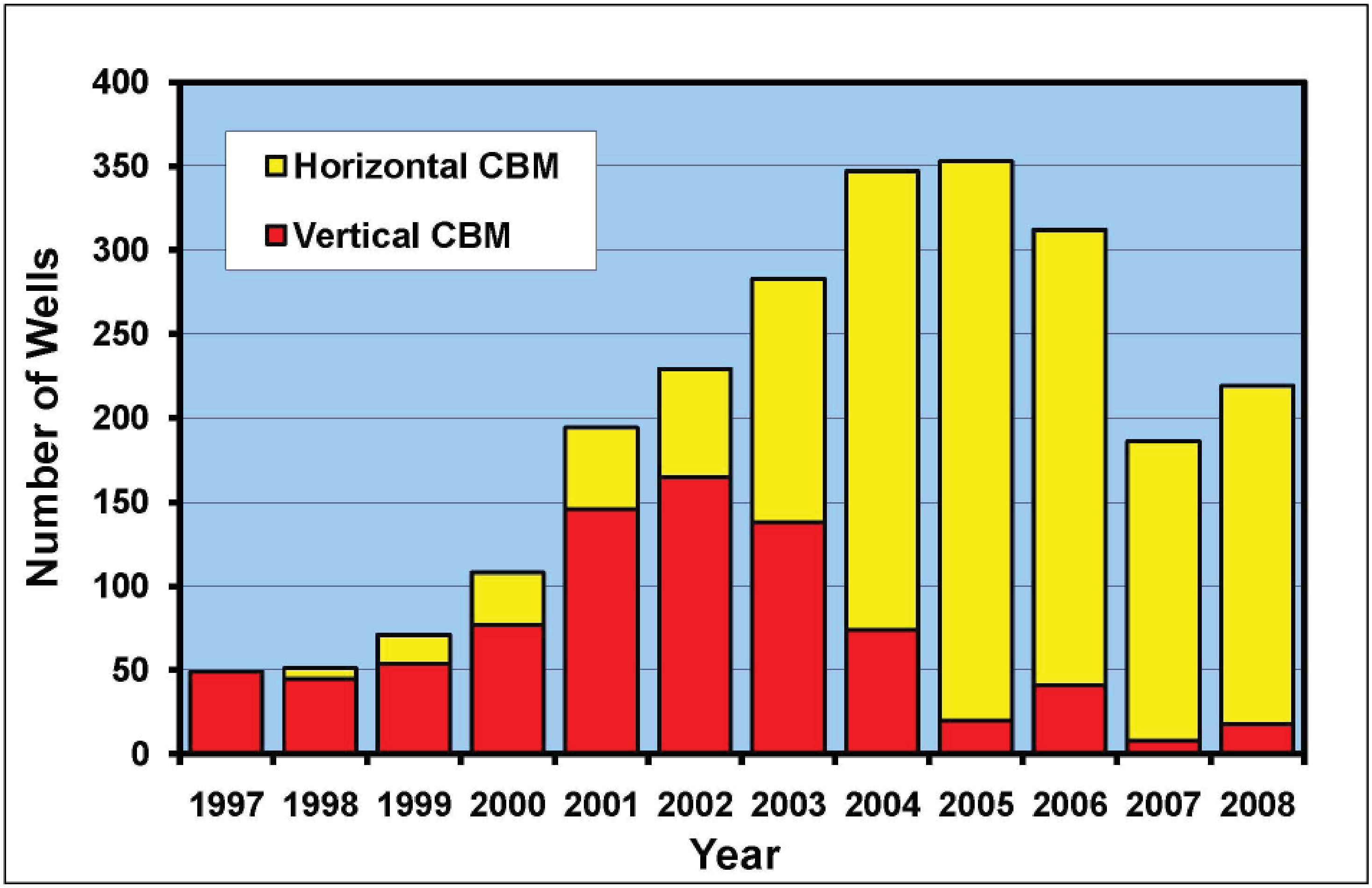


Figure 9. Histogram of horizontal coalbed-methane (CBM) wells in Oklahoma (1998–2008).

wells with perforations in noncoal lithologies have been included in the CBM completions database. The proportion of gas produced from the noncoal lithologies is unknown.

The Mulky coal on the shelf may be either an impure coal (e.g., high mineral matter content < 50% by weight) or it is absent. The 506 Mulky-only wells may be more accurately considered as producing gas from the Excello Shale and should be categorized as gas-shale wells. The Excello-Mulky of northeast Oklahoma and southeast Kansas was included in a recent United States shale-gas-plays map (EIA, 2009).

From 1995 through 2008, 824 CBM wells on the shelf commingled 2 to 9 coal beds each. The thin nature of the multiple coals encountered in any well on the shelf necessitates the perforating of several coal beds for economic completions. Perforating multiple coal beds, however, precludes knowing how much gas came from each coal bed. Only the shallowest coal bed is plotted, masking the contributions of the other coal beds.

Advances in horizontal drilling since 1999 has enabled drillers to stay within coal beds 3 to 10 ft thick, and expose the well to 14–5,771 ft of coal (average lateral length of 2,182 ft from 1,532 wells) than within the < 10 ft thickness of coal in a vertical well. Although 1,565 (98%) of the horizontal CBM wells are in the basin, 27 horizontal and 8 directional wells have been drilled on the shelf.

Coals of a continuous nature are blanket-type reservoirs that do not fit into conventional gas-field boundaries. Following a short period when established gas-field boundaries were extended, the Oklahoma Corporation Commission (OCC) began in 2001 to use county names in the assignment of CBM gas fields (e.g., Le Flore County CBM Gas Area).

Many (248) wells reported as "Pennsylvanian" CBM wells do not provide the necessary details for what coal beds were perforated or on how productive they are.

ACKNOWLEDGMENTS

I thank Dan Boyd and Stan Krukowski of the Oklahoma Geological Survey for critical reviews of this report.

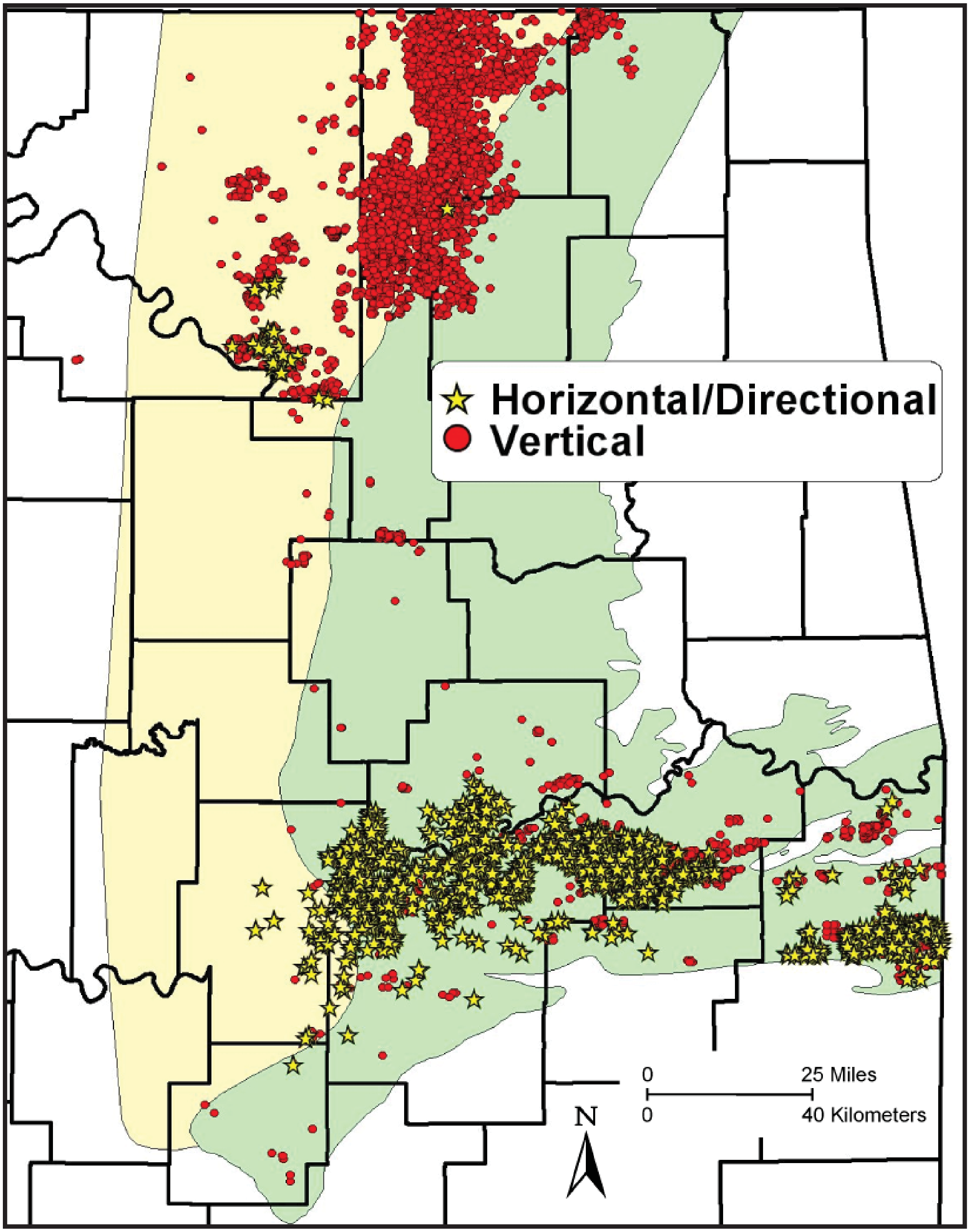


Figure 10. Map showing horizontal and directional coalbed-methane (CBM) wells in Oklahoma (1998–2008).

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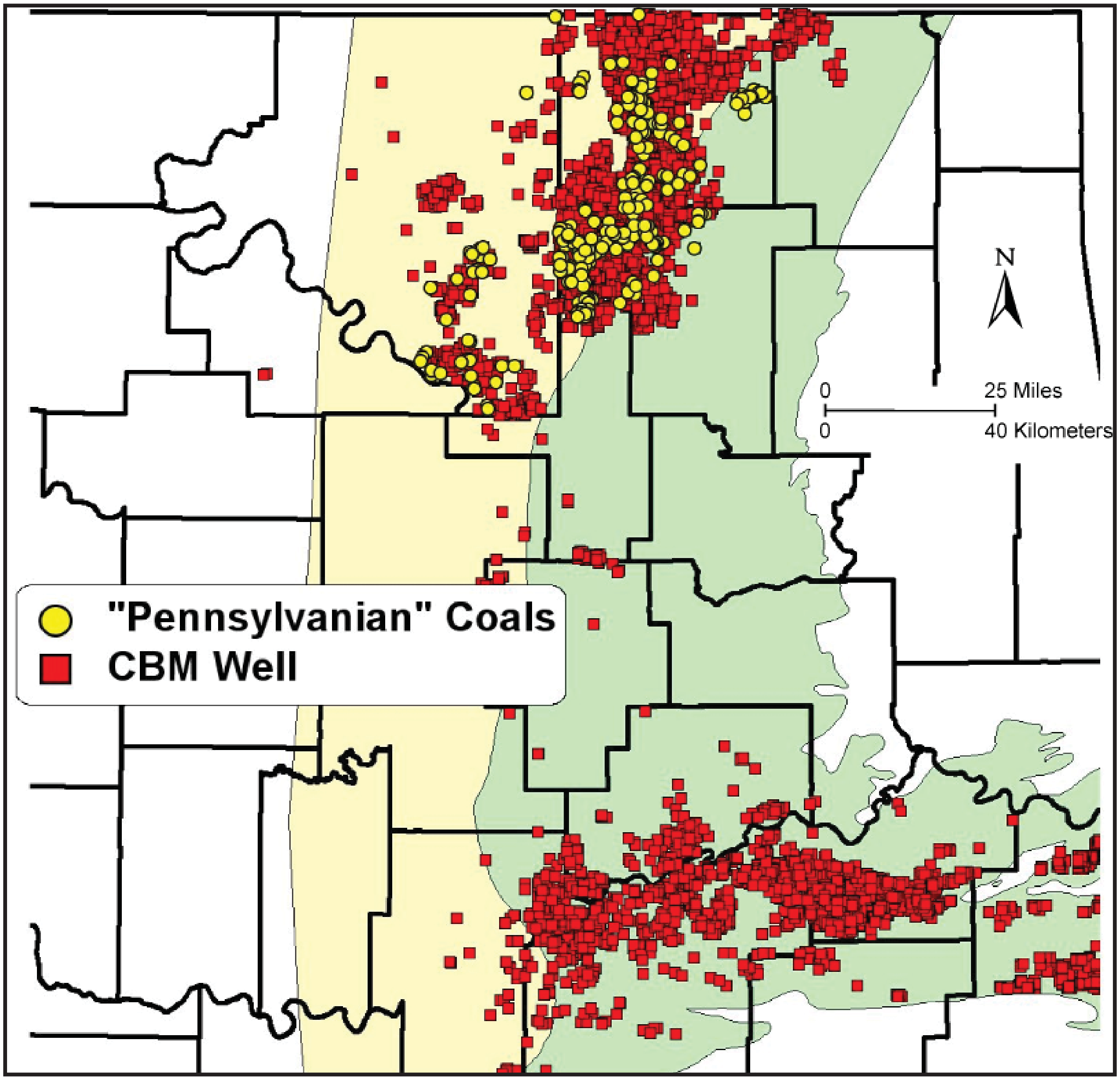
Figure 11. Map showing "Pennsylvanian" coalbed-methane (CBM) wells in Oklahoma (2005–2008).



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