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Play-Level Distributions of Estimates of Recovery Factors for a Miscible Carbon Dioxide Enhanced Oil Recovery Method Used in Oil Reservoirs in the Conterminous United States

Open-File Report 2015–1239

U.S. Department of the Interior
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U.S. Geological Survey, Reston, Virginia: 2016

Suggested citation:
Attanasi, E.D., and Freeman, P.A., 2016, Play-level distributions of estimates of recovery factors for a miscible carbon dioxide enhanced oil recovery method used in oil reservoirs in the conterminous United States: U.S. Geological Survey Open-File Report 2015–1239, 36 p., http://dx.doi.org/10.3133/ofr20151239.

ISSN 2331-1258 (online)

Contents

Figures

Tables

Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
gallon (gal)	0.003785	cubic meter (m^3)
barrel (bbl; petroleum, 1 barrel=42 gal)	0.1590	cubic meter (m^3)
thousands of cubic feet (mcf) of CO_2 per barrel of produced oil at the surface at standard conditions of 14.7 psi and 60 °F	0.3506	metric ton of CO_2 per cubic meter of produced oil at the surface at standard conditions of 14.7 psi and 60 ºF
	Pressure	
Pound-force per square inch (psi)	6.895	kilopascal (kPa)
	Permeability	
millidarcy (mD)	9.869×10^{-16}	square meter (m^2)
	Viscosity	
centipoise (cP)	1	millipascal second (mPa · s)

Abbreviations

API	American Petroleum Institute
ARI	Advanced Resources International
bbl	barrel
CO_2	carbon dioxide
CO_2-EOR	carbon dioxide (CO_2) enhanced oil recovery (EOR)
CRD	Comprehensive Resource Database
EIA	U.S. Energy Information Administration
EOR	enhanced oil recovery
ft	feet
HCPV	hydrocarbon pore volume
mcf	thousand cubic feet
mcf/bbl	thousand cubic feet per barrel
mD	millidarcy
MMP	minimum miscibility pressure
NPC	National Petroleum Council
psi	pound-force per square inch
USGS	U.S. Geological Survey
WAG	water-alternating-gas

Play-Level Distributions of Estimates of Recovery Factors for a Miscible Carbon Dioxide Enhanced Oil Recovery Method Used in Oil Reservoirs in the Conterminous United States

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Abstract

In a U.S. Geological Survey (USGS) study, recovery-factor estimates were calculated by using a publicly available reservoir simulator (CO_2 Prophet) to estimate how much oil might be recovered with the application of a miscible carbon dioxide (CO_2) enhanced oil recovery (EOR) method to technically screened oil reservoirs located in onshore and State offshore areas in the conterminous United States. A recovery factor represents the percentage of an oil reservoir's original oil in place estimated to be recoverable by the application of a miscible CO_2-EOR method. The USGS estimates were calculated for 2,018 clastic and 1,681 carbonate candidate reservoirs in the "Significant Oil and Gas Fields of the United States Database" prepared by Nehring Associates, Inc. (2012).

This report presents distributions of estimated recovery factors organized by plays in seven U.S. regions. The distributional parameters for plays containing at least three candidate reservoirs are presented in tables, and parameters for plays containing at least six candidate reservoirs are presented in boxplots. Over all the reservoirs evaluated, 90 percent of the recovery-factor estimates for clastic reservoirs fell within the range from 8.7 to 16.2 percent, and the median value of the distribution was 9.5 percent. Similarly, 90 percent of the recovery-factor estimates for carbonate reservoirs were within the range from 11.8 to 27.5 percent, and the median value of the distribution was 13.6 percent. Both distributions were right skewed.

The retention factor is the percentage of injected CO_2 that is naturally retained in the reservoir. Retention factors were also estimated in this study. For clastic reservoirs, 90 percent of the estimated retention factors were between 21.7 and 32.1 percent, and for carbonate reservoirs, 90 percent were between 23.7 and 38.2 percent. The respective median values were 22.9 for clastic reservoirs and 26.1 for carbonate reservoirs. Both distributions were right skewed. The recovery and retention factors that were calculated are consistent with the corresponding factors reported in the literature.

Introduction

Studies by the National Petroleum Council (1984), by Advanced Resources International (ARI, 2006a, b, c, d), and by ARI and the U.S. Department of Energy, National Energy Technology Laboratory (Wallace and others, 2013) have yielded estimates of the volume of oil that could potentially be produced with the application of a miscible carbon dioxide (CO_2) enhanced oil recovery (EOR) method to selected reservoirs in the United States. The results of these studies were reported at the national and regional levels, and some estimates were reported at the petroleum province level. These sources suggested that significant volumes of oil could be recovered if this tertiary recovery method had widespread application. The Oil and Gas Journal's 2014 EOR survey (Koottungal, 2014) showed that gas injection projects outnumbered projects using other tertiary recovery methods in the United States and that carbon dioxide was the most commonly used injection fluid for miscible operations.

The miscible CO_2 enhanced oil recovery process is implemented by injecting CO_2 and water into an oil reservoir where conditions of miscibility are maintained. This process is most commonly initiated after the reservoir has undergone a waterflood secondary recovery program. Under conditions of miscibility, the injected CO_2 dissolves into oil to vaporize lighter fractions of the oil and also reduce the viscosity of the residual oil (Teletzke and others, 2005).

This report presents estimates by petroleum play of recovery factors for technically recoverable oil that could be produced by the use of a miscible CO_2-EOR method. The CO_2-EOR recovery factor, as defined here, represents the fraction of the producing pattern's[1] original oil in place that would be recovered over the duration of the EOR project. For this study, it is interpreted to represent technically recoverable[2] oil because no economic screen or cutoff is applied. In particular, the recovery factors represent the percentage of original oil in place that could be recovered from the application of a miscible CO_2-EOR method, irrespective of oil prices or input costs, by using current recovery technology.

Enhanced oil recovery processes are applied at the reservoir level. According to the U.S. Energy Information Administration (EIA, 2000), a conventional oil reservoir is defined as an underground formation containing an individual and separate pool of producible oil that is confined by impermeable rock or water barriers and is characterized by a single natural pressure system. A field may consist of a single reservoir or multiple reservoirs that are not in communication but which may be associated with or related to a single structural or stratigraphic feature (U.S. Energy Information Administration, 2000). For this study, an oil reservoir is defined as having a gas-to-oil ratio of no more than 10,000 cubic feet of natural gas/1 barrel of oil at standard surface conditions (14.7 pound-forces per square inch and 60 °F).

During the CO_2-EOR process, the injected CO_2 will be miscible with the oil if the reservoir pressure is maintained at least as high as the minimum miscibility pressure (MMP) of the oil. The MMP depends on the composition of the oil and the reservoir temperature (Mungan, 1981). The formation fracture pressure, which is calculated by using an appropriate pressure gradient and depth, must also be greater than the MMP to assure that miscibility can actually be attained. In the implementation of actual CO_2-EOR programs, the reservoir pressure at completion of the waterflood stage is commonly increased to the MMP by shutting in all production wells and then injecting water into the reservoir.

For this U.S. Geological Survey (USGS) analysis, miscible candidate reservoirs were required to pass the following screening criteria originally based on the 1984 "Enhanced Oil Recovery" study by the National Petroleum Council (NPC, 1984). The minimum miscibility pressure was required to be at least 400 pound-forces per square inch (psi) below the reservoir fracture pressure, the API (American Petroleum Institute) gravity of the oil had to be at least 25 degrees API (ºAPI), the depth of the reservoir had to be at least 2,500 feet, and the viscosity of the oil had to be less than 10 centipoise (National Petroleum Council, 1984).[3] The set of feasible carbonate and clastic candidate reservoirs was further reduced by eliminating reservoirs with a net pay (interval of productive reservoir rock) of less than 5 feet or permeability values of less than 2 millidarcies (mD) or an amount of original oil in place that was less than 5 million barrels. Recovery factors for implementation of a miscible CO_2-EOR tertiary recovery method were evaluated for 2,018 clastic reservoirs and 1,681 carbonate reservoirs.[4]

Calculation of Reservoir-Specific Recovery Factors and Net CO_2 Utilization

Calculation Algorithm

CO_2 Prophet is a pattern-level oil reservoir simulator used in this USGS study to predict an individual reservoir's responses to injection of CO_2 and water. This simulator was developed for the U.S. Department of Energy by Texaco Inc. under contract No. DE–FC22–93BC14960 and was described by Dobitz and Prieditis (1994). It predicts the reservoir's response to injection of CO_2 and water by generating fluid flow streamlines between injection and production wells and models the physical displacement and recovery of oil along streamtubes formed when the streamlines are used as boundaries (Willhite, 1986; Green and Willhite, 1998). A version of this simulator has been applied to regional and national assessments for the U.S. Department of Energy by Advanced Resources International (2006a, b, c, d; Wallace and others, 2013). Analysts in the petroleum industry use the CO_2 Prophet simulator as a scoping tool to evaluate potential candidate reservoirs (Hsu and others, 1995).

The recovery factors are computed on the basis of a single pattern of injection and production wells that is assumed to represent the average for the reservoir.[5] The recovery factor for the CO_2-EOR method as reported here represents the fraction, in

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[1]A pattern is a configuration of injection and production wells.

[2]Technically recoverable resources are resources in accumulations producible by using current recovery technology and industry practices but without reference to economic profitability.

[3]The list of candidates evaluated included four reservoirs with operating CO_2-EOR programs that failed to meet one of the screening criteria.

[4]Reservoirs were defined according to lithologic type, either clastic or carbonate. Clastic reservoirs are composed of clastic sedimentary rocks, which consist principally of broken rock fragments from preexisting rocks of any kind. Carbonate reservoirs are composed of carbonate sedimentary rocks formed by aqueous solution of calcium, magnesium, or iron that formed limestone and dolomites (Jackson, 1997).

[5]In commercial applications of CO_2 Prophet where pattern-specific data are available, computations for individual patterns across a reservoir could be modeled and then aggregated to arrive at an average recovery factor for the reservoir.

percent, of the pattern's original oil in place that is recovered over the duration of the EOR project and is interpreted to represent technically recoverable oil because no economic screen or cutoff is applied. Net utilization of CO_2, measured in thousands of cubic feet (mcf) of CO_2 per barrel (bbl) of oil produced (at the surface), as defined here, is the amount of CO_2 calculated that is retained in the reservoir per barrel of oil produced. It is computed as the difference between the volume of CO_2 injected at the surface and the volume of CO_2 recovered from production wells divided by the volume of oil produced. The gross amount of CO_2 injected per barrel of produced oil at the surface is sometimes referred to as gross CO_2 utilization. An estimate of the volume of CO_2 retained in the reservoir is given by the product of the net CO_2 utilization and the volume of oil produced. The retention factor is the percentage of injected CO_2 that is naturally retained in the reservoir. This percentage is calculated by dividing the amount retained (at standard surface conditions) by the amount of CO_2 injected (at surface conditions). To summarize, in this report, recovery factors and retention factors are percentages of oil recovered and CO_2 retained in the reservoir, respectively, and net CO_2 utilization is the amount of CO_2 per barrel that is retained in the reservoir and is measured in thousands of cubic feet per barrel (mcf/bbl) under standard conditions.

The objective of this report is to put into the public domain estimates of recovery factors, net CO_2 utilization values, and retention factors for the application of the miscible CO_2-EOR method to a wide range of petroleum provinces and petroleum plays. These estimates may provide the basis for subjective reconnaissance-level assessments that may be useful to industry decision makers and government policy makers.

Data Required for Calculation of Recovery Factors and Assumptions

The data demands of simulators and the scope of the national and regional assessments requiring calculation of oil recoverable from EOR methods (and the associated recovery factors) for thousands of reservoirs entail tradeoffs between the reservoir-specific data that can be assembled versus the need for simplifying assumptions that allow the assignment of default values for some reservoir parameters. The data to calculate reservoir-specific recovery factors with CO_2 Prophet were taken from the Comprehensive Resource Database (CRD) that was prepared by INTEK, Inc. under contract to the USGS. The algorithms described by M. Carolus (of INTEK, Inc.) and others (written commun., 2015) were used to estimate the values of variables needed for projecting EOR performance at the reservoir level and to complete some partial reservoir records of the "Significant Oil and Gas Fields of the United States Database" prepared by Nehring Associates, Inc. (2012). Along with augmenting the original database, the CRD includes estimates of reservoir and fluid properties used by CO_2 Prophet to compute recovery factors. In particular, the derived reservoir-specific engineering parameters included estimates of the minimum miscibility pressures, fracture pressure, formation volume factors, and pseudo-Dykstra-Parsons coefficients. The calculation of the pseudo-Dykstra-Parsons coefficient, which is a measure of reservoir heterogeneity, followed the procedure of Hirasaki, Morra, and Wilhite (1984) and Hirasaki and others (1989).

The miscible CO_2-EOR process requires reservoir pressures of at least the MMP, so the reservoir fracture pressure was required to be at least 400 psi above the MMP; otherwise, the reservoir was not evaluated. The residual oil saturation, that is, the oil saturation remaining after completion of the waterflood phase of reservoir development, is an important initial condition because it constrains the volume of oil that can be accessed by the CO_2-EOR process. For clastic reservoirs, the residual oil saturation was assumed to be 0.25 (Robl and others, 1986) and, for carbonate reservoirs, the residual oil saturation value was assumed to be 0.305 (Donald Remson, U.S. Department of Energy, written commun., 2015).

Water and CO_2 injection rates and the injection scheme over time also represent initial conditions that were required by the simulator. Injection rates for water and CO_2 were set so that the reservoir pressure remained at or above the MMP but 400 psi below the fracture pressure, and a 5-spot pattern of one production well and four injection wells was assumed (Lyons, 1996). Holtz (2014) reported that field studies show that after the initial injection of CO_2, reservoir injectivity may increase, decline, or stay unchanged. However, both Holtz (2014) and Wallace and others (2013) discussed several treatments commercially available to remediate losses in injectivity. For the computation of technically recoverable oil from the applications of a miscible CO_2-EOR method, it was assumed that any decline in injectivity was remediated.

The total injected volume of CO_2 during the EOR project was assumed to amount to 100 percent of the hydrocarbon pore volume (HCPV). The assumed injection regime had three phases: in phase 1, injected CO_2 was equivalent to 25 percent of the HCPV; in phase 2, injected CO_2 was equivalent to 35 percent of the HCPV; and in phase 3, injected CO_2 was equivalent to 40 percent of the HCPV. The ratio of water volumes injected to gas (CO_2) volumes injected during water-alternating-gas (WAG) injections in phase 1 was 1:3; the ratio in phase 2 was 1:2; and the ratio in phase 3 was 1:1.5. When the WAG ratio was tapered over the three phases, as indicated here, water was injected in greater cumulative amounts in each phase relative to the CO_2 injected.

The following additional initial conditions were assumed. Connate water and irreducible water saturation values were set to 0.2 for all reservoirs. The specific gravity for casing-head gas, with respect to air (where the specific gravity of air equals 1.0), was assumed to be 0.7. On the basis of experimental data presented in graphs by Lange (1998), a value of 0.08 was selected for the parameter representing residual oil saturation to the CO_2 solvent for all miscible CO_2-EOR reservoirs. The values of the endpoints of the relative permeability functions were based on default values for mildly water wet[6] reservoirs suggested by Michael Stein (BP [retired], written commun., 2014).[7]

The CO_2 Prophet simulator represents a simplification of the actual physical processes and does not capture the chemical processes that would be described by a sophisticated compositional model. Nor does the modeling capture the unanticipated operational factors such as fractures or thief zones that affect the actual recovery factors. The advantage of applying even rudimentary simulators such as CO_2 Prophet for calculating recovery by the CO_2-EOR method is that oil attributed to the EOR program is clearly delineated from the oil produced under a secondary recovery program.

Distributions of Recovery Factors and Estimates of Net CO_2 Utilization

Format of Results

The evaluated oil reservoirs were grouped according to lithologic type, either clastic or carbonate, and by play within petroleum provinces of seven regions in the conterminous United States. Plays were defined according to the scheme used in the U.S. Geological Survey's 1995 National Oil and Gas Assessment (NOGA; Beeman and others, 1996; Gautier and others, 1996). The beginning of the 3- or 4-digit play code identifies the 1- or 2-digit province code (for example, play 1003, Lower Bakersfield Arch, is in province 10, the San Joaquin Basin Province). Figure 1 shows petroleum provinces identified as containing oil reservoirs that are potential candidates for the application of a miscible CO_2-EOR method.

Candidate oil reservoirs for miscible CO_2-EOR that were evaluated were located in onshore and State offshore areas in the conterminous United States.[8] Reservoirs located in Federal offshore areas were excluded, as were unconventional oil reservoirs such as those in the Bakken and the Eagle Ford plays. The results are presented by region. For each region, the initial table (tables 1, 3, 5, 8, 11, 14, 17) lists the play number, the count of clastic and carbonate candidate reservoirs, the province name, and the formal play name as used by Beeman and others (1996). The next tables (tables 2, 4, 6, 7, 9, 10, 12, 13, 15, 16, 18) list the characteristics of the distributions of recovery factors and the median value of the associated net CO_2 utilization estimates for each play containing at least three candidate oil reservoirs. Boxplots characterize the recovery-factor distributions and provide a visual representation of the tabular data (figs. 2–12). Boxplots show only plays that have at least six candidate oil reservoirs.

Recovery-factor estimates calculated by CO_2 Prophet for each of the candidate reservoirs are presented by play as a distribution that characterizes the play. The median values in the tables represent the central tendency of the distributions. The difference between the first and third quartile in the table is called the interquartile range, and it should be interpreted to represent the dispersion or spread of the recovery-factor distribution. In the boxplots, the interquartile range is represented as the height of the box; that is, the distance between the 25th percentile (bottom of box) and the 75th percentile (top of box). The median value is the thick line. The minimum value of the dashed line outside the box is the smallest value of the data within 1.5 times the interquartile range below the 25th percentile, and the maximum value of the dashed vertical line is the largest value within 1.5 times the interquartile range above the 75th percentile. Play-level distributions of simulated recovery factors were computed for clastic and (or) carbonate reservoirs.

The nature of the skewness of the distribution can be inferred from the position of the median on the boxplots. An idealized symmetric distribution would display the darkened median line midway between the ends of the rectangular box with the minimum and maximum values extending out an equal distance from the 1st and 3d quartiles, respectively. A right-skewed distribution has many small values and a few large values, with the average of all values being larger than the median value. For a right-skewed-distribution boxplot, the vertical distances between the minimum and first quartile to the median value are much smaller than the vertical distances from the median to the third quartile and maximum value. A left-skewed distribution is just the opposite of a right-skewed distribution.

Because some of the provinces have only a small number of plays, the play distribution properties were grouped into the region for displaying in tabular form and as play boxplots.

[6]A water-wet reservoir denotes a condition in which a thin film of water coats the formation and aids in oil transport (Schlumberger Oilfield Glossary, 2015).

[7]In particular, the following parameters were specified: the endpoint relative permeability of oil at connate water was 1, the endpoint relative permeability of water at residual oil saturation was 0.3, the endpoint relative permeability of CO_2 at CO_2 saturation was 0.4, the endpoint relative permeability of gas-to-connate-water saturation was 0.4, and the exponents on the relative permeability equations were 2.0.

[8]Reservoirs in Alaska (Region 1) were excluded because North Slope reservoirs are developed with horizontal injection and production wells and the calculations of CO_2 Prophet assume vertical injection and production wells. According to available data, Hawaii has no oil reservoirs.

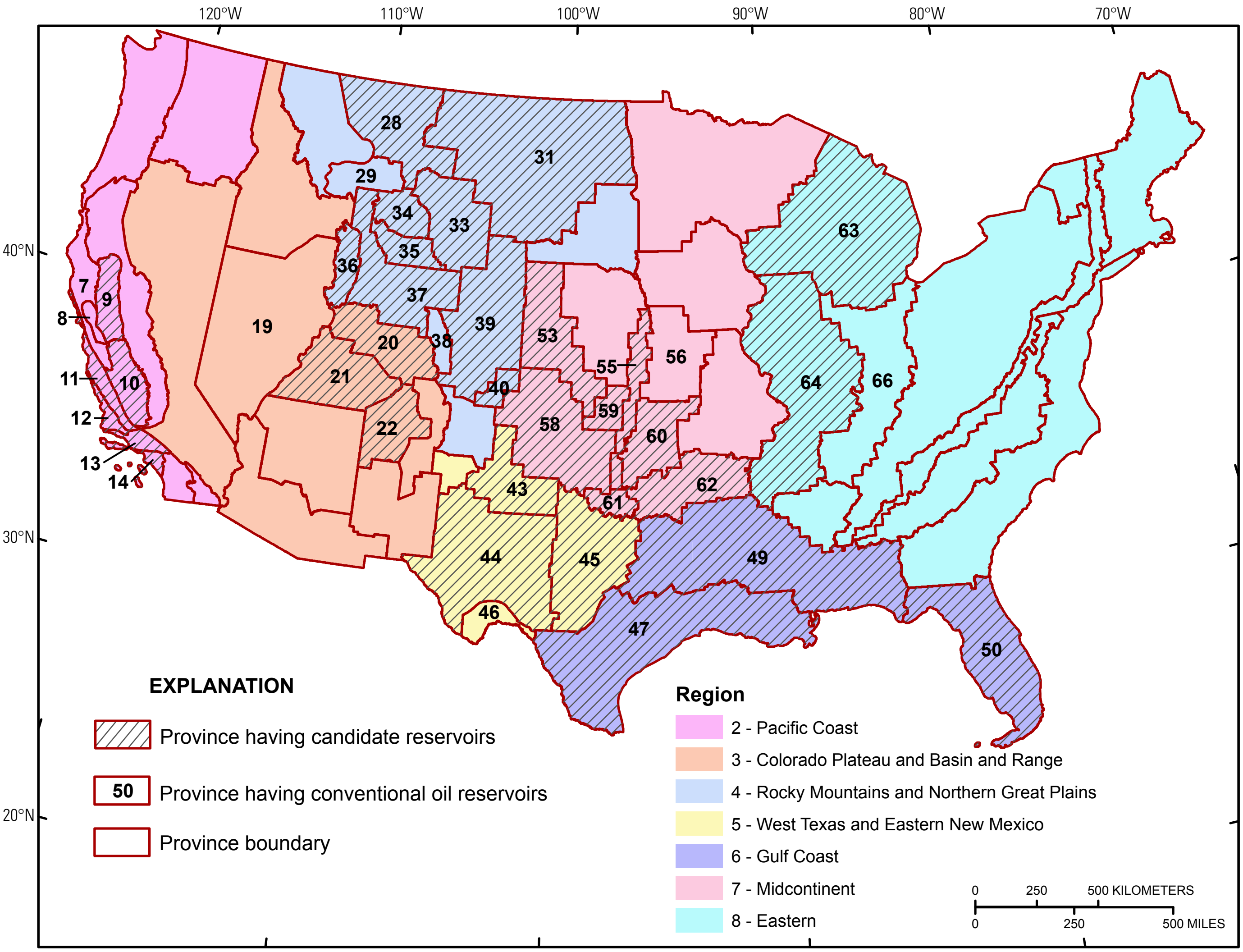

Figure 1. Map of the conterminous United States showing the petroleum province boundaries in seven of the eight regions used in the U.S. Geological Survey's 1995 National Oil and Gas Assessment (NOGA); boundaries are from Beeman and others (1996). Provinces labeled by codes contain conventional oil reservoirs; that is, reservoirs that have a gas-to-oil ratio of no more than 10,000 cubic feet of natural gas/1 barrel of oil at standard surface conditions and that are listed in the database by Nehring Associates, Inc. (2012). See tables 1, 3, 5, 8, 11, 14, and 17 for province names; play numbers in these tables begin with a 1- or 2-digit province code corresponding to the codes on this map. Stripes designate provinces having oil reservoirs that are candidates for miscible carbon dioxide enhanced oil recovery (CO_2-EOR) as indicated by use of the reservoir simulator CO_2 Prophet. Alaska (Region 1) is not shown because North Slope reservoirs are developed with horizontal injection and production wells, whereas the calculations of CO_2 Prophet assume vertical injection and production wells.

Discussion of Play-Level Recovery-Factor Distributions for Regions

Table 1 lists the plays in Region 2, the Pacific Coast Region, that contain candidate oil reservoirs. Region 2 has 103 clastic candidate reservoirs and no carbonate candidate reservoirs. Table 2 provides the median net CO_2 utilization factor and the distributional parameters for recovery factors for plays that contain at least three candidate reservoirs for a lithology type. Figure 2 shows boxplots of recovery-factor data for the five Pacific Coast Region plays that contain at least six candidate reservoirs for a lithology type. The median values of the recovery factors across the five plays are remarkably close, and the shapes of the distributions in figure 2 are roughly symmetric or right skewed. The variability of the recovery-factor distributions as represented by the height of the box is directly related to the variability of the reservoir characteristics that affect the CO_2 Prophet recovery-factor computations.

Table 3 lists the plays in Region 3, the Colorado Plateau and Basin and Range Region, that contain candidate oil reservoirs. Table 4 provides the median net CO_2 utilization factor and the distributional parameters for recovery factors for plays that contain at least three candidate reservoirs for a lithology type. Figures 3*A* and 3*B* show boxplots for the plays containing the clastic and carbonate reservoirs, respectively. Within this region, the median recovery factor for carbonate reservoirs in one play (13.06 percent) exceeds those for clastic reservoirs in three plays (8.88–11.12 percent).

Table 5 lists the plays in Region 4, the Rocky Mountains and Northern Great Plains Region, that contain candidate oil reservoirs. Table 6 provides the median net CO_2 utilization factor and the distributional parameters for recovery factors for plays in Region 4, excluding those in the Powder River Basin Province (which are described below). Figures 4*A* and 4*B* show boxplots of recovery-factor data for the clastic and carbonate reservoirs, respectively, in Region 4 plays outside of the Powder River Basin Province. Generally, the median recovery factors for the clastic reservoirs are lower than the median recovery factors for the carbonate reservoirs in Region 4. This result was not unexpected because the assumed residual oil saturation after waterflood for carbonate reservoirs (0.305, as described above) is 22 percent greater than the assumed value for clastic reservoirs (0.25).

Table 7 and figure 5 show the distributional parameters of recovery-factor data and boxplots for the clastic reservoirs in the plays of the Powder River Basin Province. The province lacked a carbonate reservoir that could be a candidate. With the exception of play 3309, the values of the median recovery factors are consistent across the province, and the shapes are either roughly symmetric or right skewed. Play 3309 has only a few reservoirs, and two or three of them have high recovery factors that affect the median.

The plays containing candidate reservoirs in Region 5, the West Texas and Eastern New Mexico Region, are listed in table 8 and are identified as being in either the Permian Basin Province (province 44) or the Bend Arch-Fort Worth Basin Province (province 45). Table 9 and figures 6*A* and 6*B* present the results for the Permian Basin Province. For the Permian Basin Province, with the exception of plays 4409 and 4410, the median recovery factors for the clastic reservoirs are remarkably similar. Figure 6 shows that there is slightly more variability in recovery factors computed for the carbonate reservoirs. With the exception of play 4410, the shapes of the recovery-factor distributions for both clastic and carbonate reservoirs are either roughly symmetric or right skewed. The high recovery factors for play 4410 are explained by data from the CRD that show a relatively large number of reservoirs with favorable (low) pseudo-Dykstra-Parsons coefficients.

Table 8 lists the plays in the Bend Arch-Fort Worth Basin Province that contain candidate reservoirs, and table 10 and figures 7*A* and 7*B* present distributional parameters. Figures 7*A* and 7*B* show that recovery-factor distributions as roughly symmetric or right skewed. Median values of the recovery-factor distributions for carbonate reservoirs are generally greater than the median values of the recovery-factor distributions for clastic reservoirs.

Table 11 lists the plays in Region 6, the Gulf Coast Region, that contain candidate reservoirs. Table 12 and figures 8*A* and 8*B* relate to candidate reservoirs in the Western Gulf Province (province 47), and table 13 and figures 9*A* and 9*B* relate to the Louisiana-Mississippi Salt Basins Province (province 49). Figure 8*A* shows a very small range in the median values across the recovery-factor distributions for clastic reservoirs. The shapes of these distributions are either roughly symmetric or right skewed.

Table 13 and figures 9*A* and 9*B* show parameters of the recovery factors for candidate clastic and carbonate reservoirs within plays in the Louisiana-Mississippi Salt Basins Province. With the exception of the clastic reservoirs in plays 4901 and 4938, the distribution shape of all other plays with candidate reservoirs in the province is either roughly symmetric or right skewed. Play 4901 has only six candidate reservoirs, so two or three reservoirs with high recovery factors are influential. A similar pattern is shown for play 4938, which has only 16 candidate reservoirs. Median values of the recovery-factor distributions for carbonate reservoirs are generally greater than the median values of the recovery-factor distributions for clastic reservoirs.

Table 14 lists the plays in Region 7, the Midcontinent Region, that contain candidate reservoirs. Table 15 provides the median net CO_2 utilization and the distributional parameters for recovery factors for Region 7 plays, excluding plays in the Anadarko Basin Province (province 58). Figures 10*A* and 10*B* show boxplots of recovery-factor data for the clastic and carbonate reservoirs in Region 7 plays outside of the Anadarko Basin Province (province 58). Table 16 and figures 11*A* and 11*B* show data for the Anadarko Basin Province. For the plays outside of the Anadarko Basin Province, median values of the recovery-factor distributions for carbonate reservoirs are larger than median values of the recovery-factor distributions for clastic reservoirs.

The distributional shapes for clastic and carbonate reservoirs are either roughly symmetric or right skewed. The same remarks apply to the distributional properties of the Anadarko Basin Province as shown in table 16 and figures 11*A* and 11*B*.

Table 17 lists plays having candidate reservoirs in Region 8, the Eastern Region. Table 18 and figures 12*A* and 12*B* show the recovery-factor distributional parameters for clastic and carbonate candidate reservoirs. Reservoirs are located in the Michigan Basin Province (province 63) and the Illinois Basin Province (province 64). Once again, the shapes of the recovery-factor distributions are either roughly symmetric or right skewed.

Summary and Conclusions

Baseline estimates of recovery factors for the application of a miscible CO_2-EOR method to technically suitable oil reservoirs located in onshore and State offshore areas in the conterminous United States were calculated by using the CO_2 Prophet reservoir simulator (Dobitz and Prieditis, 1994). Calculations included 2,018 clastic reservoirs and 1,681 carbonate reservoirs that were screened as potential miscible CO_2-EOR candidates by using the criteria published by the National Petroleum Council (NPC, 1984). Reservoir data were from the database by Nehring Associates, Inc. (2012), and supplemental engineering parameters were computed according to algorithms described by M. Carolus (of INTEK, Inc.) and others (written commun., 2015). The estimates are presented in this report as distributions categorized by plays from Beeman and others (1996) and Gautier and others (1996). The play distribution properties are presented in tabular form and as boxplots. Most of the distributions are right skewed or roughly symmetrical. The right-skewed distributions show a concentration of the number of reservoirs at the lower end of the spectrum of recovery factors and few reservoirs having high recovery factors. Overall, 90 percent of the recovery-factor estimates for clastic reservoirs fell within the range from 8.7 to 16.2 percent, and, similarly, 90 percent of the recovery-factor estimates for carbonate reservoirs were within the range from 11.8 to 27.5 percent. Figures 13*A* and 13*B* show the overall distributions to be right skewed. The median recovery-factor value for all of the clastic reservoirs evaluated was 9.5 percent, and the median value for all of the carbonate reservoirs evaluated was 13.6 percent. The higher recovery factors for carbonate reservoirs when compared with recovery factors for clastic reservoirs are consistent with data reported by Christensen and others (2001). The corroboration of the results with empirical observations seems to imply that the recovery-factor distributions presented here should be considered to be relatively robust.

Recall that net CO_2 utilization is an estimate of the CO_2 in thousands of cubic feet (mcf) at the surface per barrel (bbl) produced that is retained in the reservoir. Overall, the median net CO_2 utilization value estimated for clastic reservoirs is 5.95 mcf/bbl and the value estimated for carbonate reservoirs is 5.24 mcf/bbl. The retention factor is the percentage of the CO_2 injected into the reservoir that is not produced and that is assumed to be retained in the formation. For clastic reservoirs, 90 percent of the estimated retention factors were between 21.7 and 32.1 percent, and, for carbonate reservoirs, 90 percent were between 23.7 and 38.2 percent. The respective median values were 22.9 for clastic reservoirs and 26.1 for carbonate reservoirs. With the exception of a few outlier carbonates (less than 0.7 percent), the retention estimates are consistent with empirical data published by Olea (2015). Figures 14*A* and 14*B* indicate that both retention-factor distributions are right skewed.

The higher carbonate recovery factors are directly attributable to the assumptions about the residual oil saturation after waterflooding. The assumptions implied that for carbonate reservoirs, such as those found in the Permian Basin, the primary and waterflood recovery processes were much less efficient in recovering oil in place than the same primary and waterflood processes were for clastic reservoirs, resulting in a higher residual oil saturation for carbonate reservoirs. The difference was about 22 percent higher than for similar clastic reservoirs. Consequently, the miscible CO_2-EOR recovery factors for carbonate reservoirs are generally higher than those for clastic reservoirs.

Another assumption that affects the recovery factor is the amount of CO_2 that is injected into the reservoir relative to the amount of the HCPV. The past practices (Merchant, 2010) rarely reached 100 percent as assumed in this study; however, industry practices seem to be moving toward higher amounts. If the relative cost of CO_2 were to decline substantially, injection volumes could exceed 100 percent of the HCPV on a regular basis. Numerical sensitivity studies showed that going from injections equivalent to 100 percent of the HCPV to injections equivalent to 150 percent added about 2 to 3 percentage points to the recovery factor. Overall, this increment represented about a 14-percent increase in the mean recovery factor for the representative reservoir. However, the increase extends the duration of the EOR program by about 50 percent, and oil production rates during the latter years are substantially reduced.

The recovery-factor estimates lead to a number of possibilities for further study. For example, can one identify specific play characteristics among the reservoir conditions or fluid properties that have an influence on the recovery factor? Can the relative strength of these specific characteristics be ascertained? The limitations of the recovery factors presented here, however, should be kept in mind. The limitations relate to the data that support the estimates being based on the characteristics of a representative pattern. Within an individual reservoir, there will be spatial variations in the reservoir characteristics leading a distribution of recovery-factor estimates across patterns that should be probabilistically aggregated to the reservoir level.

Acknowledgments

The authors thank Peter Warwick and Richard Olea (both of the U.S. Geological Survey) for their reviews and suggestions, and we also thank Elizabeth Good (USGS) for excellent and comprehensive editorial work and Jeannette Foltz (USGS) for layout and production.

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Table 1. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 2, the Pacific Coast Region.

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 1 or 2 digits of the play numbers. For example, play 903 is in province 9, the Sacramento Basin Province. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
903	1	–	Sacramento Basin	Western Winters through Domingene.
1002	4	–	San Joaquin Basin	Southeast Stable Shelf.
1003	18	–	San Joaquin Basin	Lower Bakersfield Arch.
1004	5	–	San Joaquin Basin	West Side Fold Belt Sourced by Post-Lower Miocene Rocks.
1005	17	–	San Joaquin Basin	West Side Fold Belt Sourced by Pre-Middle Miocene Rocks.
1006	5	–	San Joaquin Basin	Northeast Shelf of Neogene Basin.
1007	1	–	San Joaquin Basin	Northern Area Non-Associated Gas.
1008	6	–	San Joaquin Basin	Tejon Platform.
1107	3	–	Central Coastal	Western Cuyama Basin.
1301	4	–	Ventura Basin	Paleogene-Onshore.
1302	21	–	Ventura Basin	Neogene-Onshore.
1303	1	–	Ventura Basin	Pliocene Stratigraphic.
1401	3	–	Los Angeles Basin	Santa Monica Fault System and Las Cienegas Fault and Block.
1403	6	–	Los Angeles Basin	Newport-Inglewood Deformation Zone and Southwestern Flank of Central Syncline.
1404	2	–	Los Angeles Basin	Whittier Fault Zone and Fullerton Embayment.
1405	5	–	Los Angeles Basin	Northern Shelf and Northern Flank of Central Syncline.
1407	1	–	Los Angeles Basin	Chino Marginal Basin, Puente and San Jose Hills, and San Gabriel Valley Marginal Basin.

Table 2. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in Region 2, the Pacific Coast Region.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 1. Only plays containing at least three candidate reservoirs by lithology type are shown here. Only clastic reservoirs were identified in Region 2, and so no carbonate reservoirs are listed. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
		Clastic reservoirs					
1002	4	8.46	8.63	8.85	9.12	9.42	5.56
1003	18	8.78	9.01	9.26	9.49	13.15	6.42
1004	5	8.60	8.85	8.91	9.47	9.59	5.68
1005	17	8.70	9.17	9.71	12.40	13.53	5.99
1006	5	8.36	9.06	9.18	9.36	13.51	5.36
1008	6	8.18	8.72	9.18	11.72	12.90	5.85
1107	3	8.54	9.07	9.60	10.94	12.29	4.70
1301	4	8.76	9.20	9.36	10.17	12.57	5.34
1302	21	8.71	9.35	9.52	10.12	18.85	6.15
1401	3	8.17	8.66	9.15	9.66	10.17	5.48
1403	6	8.72	9.10	9.24	11.71	19.30	5.28
1405	5	8.16	8.80	12.33	12.45	17.06	4.68

Clastic reservoirs

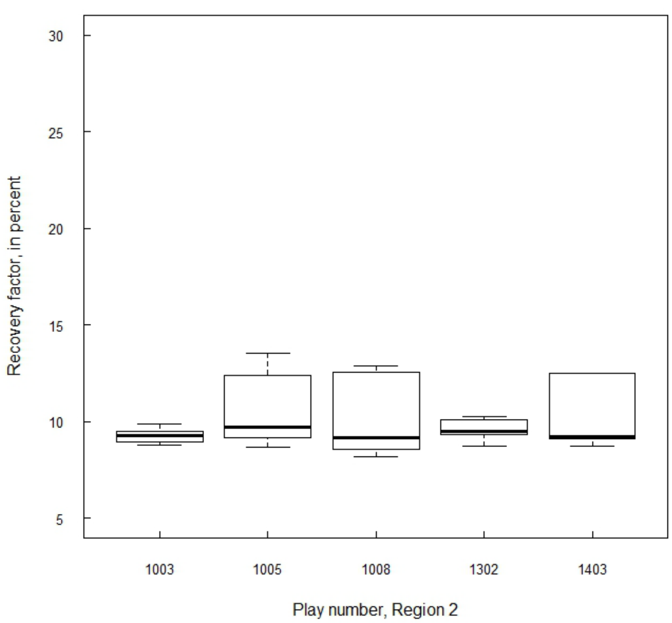

Figure 2. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from clastic oil reservoirs in plays within Region 2, the Pacific Coast Region. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 1. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here. Only clastic reservoirs were identified in this region.

Table 3. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 3, the Colorado Plateau and Basin and Range Region.

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
2002	10	–	Uinta-Piceance Basin	Uinta Tertiary Oil and Gas.
2005	2	–	Uinta-Piceance Basin	Permian-Pennsylvanian Sandstones and Carbonates.
2102	–	15	Paradox Basin	Porous Carbonate Buildup.
2204	3	–	San Juan Basin	Entrada.
2206	1	–	San Juan Basin	Basin Margin Dakota Oil.
2207	10	–	San Juan Basin	Tocito/Gallup Sandstone Oil.

Table 4. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in Region 3, the Colorado Plateau and Basin and Range Region.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 3. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
Clastic reservoirs							
2002	10	8.15	9.06	9.78	11.20	18.17	6.58
2204	3	8.84	8.86	8.88	9.48	10.07	6.41
2207	10	9.23	9.34	11.12	12.87	13.51	6.15
Carbonate reservoirs							
2102	15	12.25	12.62	13.06	17.81	18.35	5.59

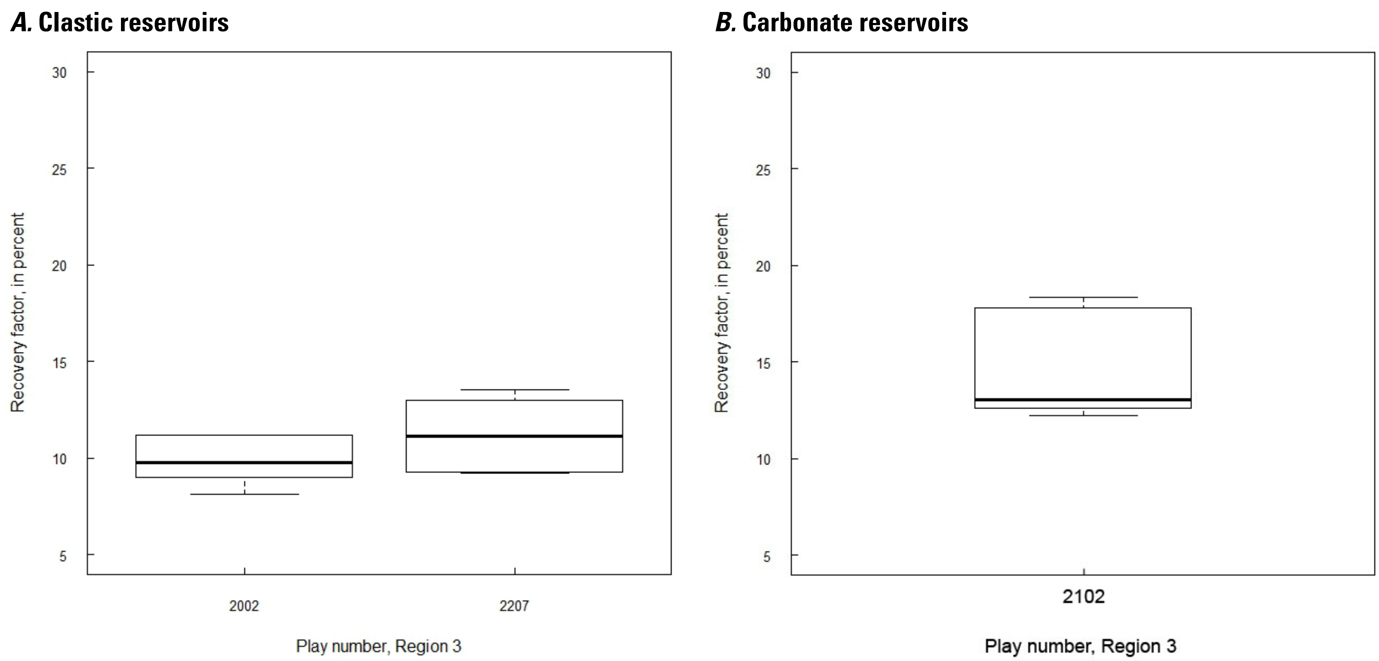

Figure 3. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within Region 3, the Colorado Plateau and Basin and Range Region. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 3. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 5. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 4, the Rocky Mountains and Northern Great Plains Region.

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
2805	–	5	North-Central Montana	Devonian-Mississippian Carbonates.
2806	11	–	North-Central Montana	Tyler Sandstone.
2808	2	–	North-Central Montana	Jurassic-Cretaceous Sandstones.
3101	–	115	Williston Basin	Madison (Mississippian).
3102	–	50	Williston Basin	Red River (Ordovician).
3103	–	31	Williston Basin	Middle and Upper Devonian (Pre-Bakken-Post-Prairie Salt).
3105	–	11	Williston Basin	Pre-Prairie Middle Devonian and Silurian.
3106	11	–	Williston Basin	Post-Madison through Triassic Clastics.
3107	1	–	Williston Basin	Pre-Red River Gas.
3302	21	–	Powder River Basin	Basin Margin Anticline.
3304	45	–	Powder River Basin	Upper Minnelusa Sandstone.
3306	14	–	Powder River Basin	Fall River Sandstone.
3307	27	–	Powder River Basin	Muddy Sandstone.
3309	11	–	Powder River Basin	Deep Frontier Sandstone.
3310	2	–	Powder River Basin	Turner Sandstone.
3312	9	–	Powder River Basin	Sussex-Shannon Sandstone.
3313	16	–	Powder River Basin	Mesaverde-Lewis.
3402	10	13	Big Horn Basin	Basin Margin Anticline.
3406	–	3	Big Horn Basin	Phosphoria Stratigraphic.
3502	6	1	Wind River Basin	Basin Margin Anticline.
3503	1	–	Wind River Basin	Deep Basin Structure.
3504	3	–	Wind River Basin	Muddy Sandstone Stratigraphic.
3515	1	–	Wind River Basin	Shallow Tertiary-Upper Cretaceous Stratigraphic.
3604	1	2	Wyoming Thrust Belt	Absaroka Thrust.
3701	2	–	Southwestern Wyoming	Rock Springs Uplift.
3702	1	–	Southwestern Wyoming	Cherokee Arch.
3703	9	–	Southwestern Wyoming	Axial Uplift.
3704	3	–	Southwestern Wyoming	Moxa Arch-LaBarge.
3707	9	2	Southwestern Wyoming	Platform.
3801	1	–	Park Basins	Cretaceous-Upper Jurassic Structural.
3901	3	–	Denver Basin	Pierre Shale Sandstones.
3905	146	–	Denver Basin	Dakota Group (Combined J and D Sandstones).
3907	2	–	Denver Basin	Basin-Margin Structural.
3908	2	–	Denver Basin	Permian-Pennsylvanian.
4004	1	–	Las Animas Arch	Lower Pennsylvanian (Morrowan) Sandstone Oil, Gas, and Natural Gas Liquids.
4005	–	6	Las Animas Arch	Mississippian Carbonate.

Table 6. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in Region 4, the Rocky Mountains and Northern Great Plains Region, excluding plays in the Powder River Basin Province.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 5. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
Clastic reservoirs							
2806	11	8.70	8.86	8.93	9.06	9.20	5.59
3106	11	8.99	9.56	9.77	13.17	16.29	5.29
3402	10	8.55	9.45	9.56	10.44	14.00	5.85
3502	6	9.09	9.32	9.60	9.89	17.10	5.18
3504	3	9.50	9.51	9.51	9.68	9.84	6.68
3703	9	9.11	9.46	9.65	10.12	12.83	6.16
3704	3	9.62	13.62	17.63	17.79	17.95	5.03
3707	9	8.38	9.12	9.22	9.52	11.19	5.79
3901	3	8.98	9.10	9.22	9.26	9.29	6.20
3905	146	8.50	8.93	9.22	9.62	16.99	5.92
Carbonate reservoirs							
2805	5	12.00	12.26	12.28	12.35	16.77	4.92
3101	115	11.21	12.55	13.02	15.24	26.77	6.05
3102	50	12.54	12.92	13.19	17.88	18.67	6.38
3103	31	12.33	12.96	13.32	17.75	24.33	6.13
3105	11	12.39	12.98	13.23	13.47	18.27	5.66
3402	13	10.97	11.67	13.42	14.59	22.33	4.86
3406	3	12.94	12.95	12.96	15.80	18.64	4.80
4005	6	12.58	12.64	14.61	16.83	24.11	5.30

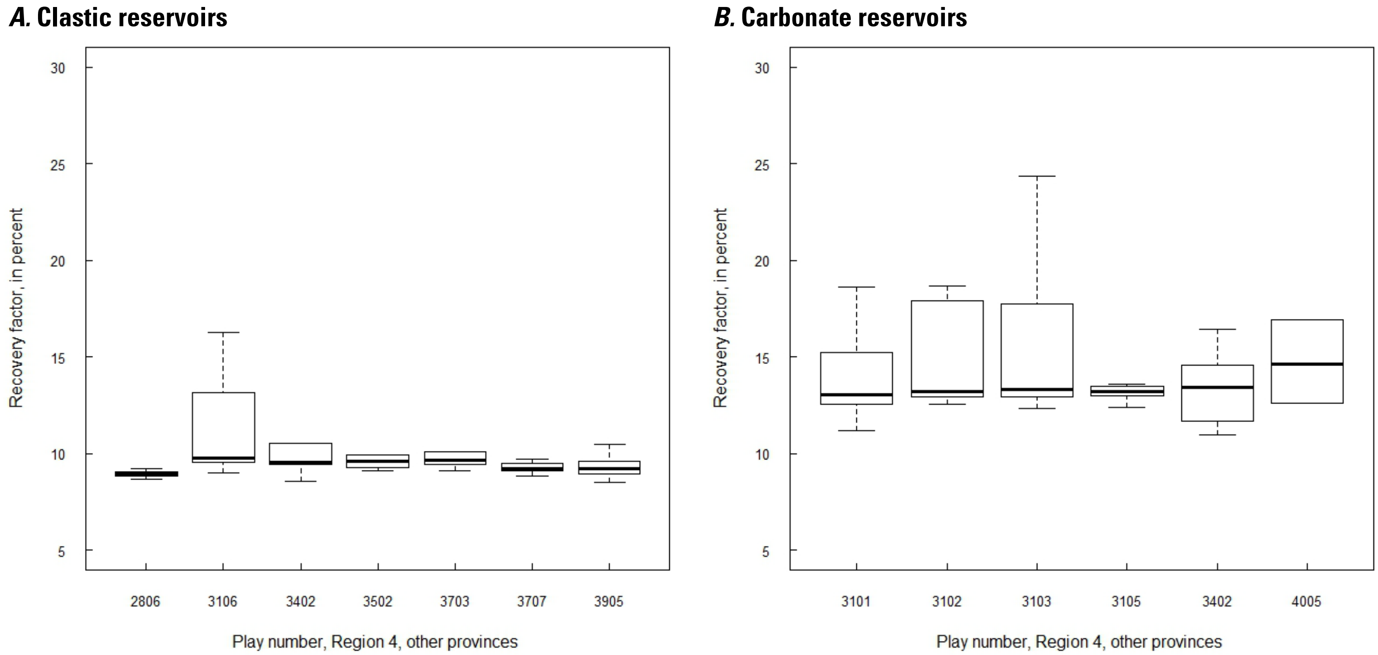

Figure 4. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within Region 4, the Rocky Mountains and Northern Great Plains Region, excluding plays in the Powder River Basin Province. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 5. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 7. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in the Powder River Basin Province of Region 4.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 5. Only plays containing at least three candidate reservoirs by lithology type are shown here. Only clastic reservoirs were identified in the Powder River Basin Province, and so no carbonate reservoirs are listed. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
Clastic reservoirs							
3302	21	8.43	9.25	9.50	9.83	17.33	5.31
3304	45	8.90	9.23	9.65	11.86	18.44	5.73
3306	14	9.16	9.64	9.79	12.74	18.42	6.44
3307	27	8.37	9.54	9.91	10.24	17.83	6.48
3309	11	9.74	10.02	13.43	13.92	14.15	6.27
3312	9	9.61	9.96	10.05	10.11	14.29	7.13
3313	16	9.45	9.61	9.85	11.46	13.75	6.34

Clastic reservoirs

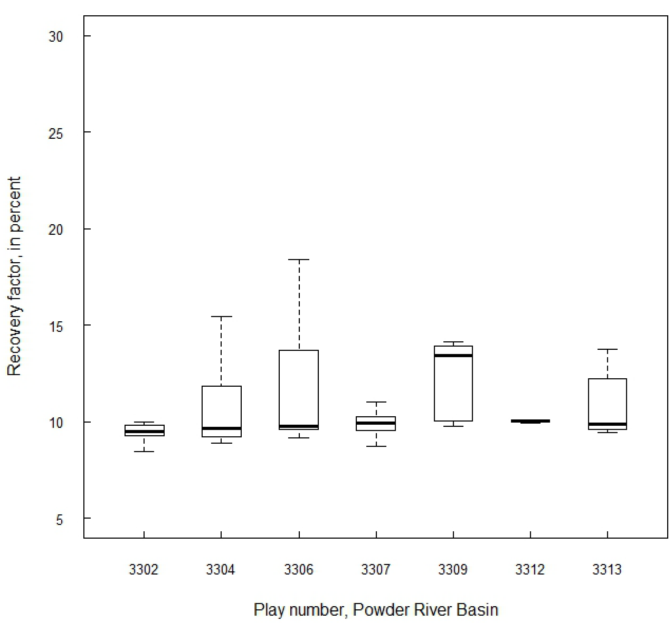

Figure 5. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from clastic oil reservoirs in plays within the Powder River Basin Province of Region 4. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 5. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here. Only clastic reservoirs were identified in this province.

Table 8. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 5, the West Texas and Eastern New Mexico Region.

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
4401	–	1	Permian Basin	Pre-Pennsylvanian, Delaware-Val Verde Basins.
4402	17	107	Permian Basin	Pre-Pennsylvanian, Central Basin Platform.
4403	1	58	Permian Basin	Pre-Pennsylvanian, Northwestern and Eastern Shelves.
4404	3	4	Permian Basin	Lower Pennsylvanian (Bend) Sandstone.
4405	2	31	Permian Basin	Horseshoe Atoll, Upper Pennsylvanian-Wolfcampian.
4406	39	111	Permian Basin	Upper Pennsylvanian, Northwestern and Eastern Shelves, Northern Delaware and Midland Basins and Northern Central Basin Platform.
4407	13	16	Permian Basin	Upper Pennsylvanian and Lower Permian Shelf, Slope and Basin Sandstones.
4408	–	20	Permian Basin	Wolfcampian Carbonate, Eastern and Southern Margins of the Central Basin Platform.
4409	30	2	Permian Basin	Spraberry-Dean.
4410	21	164	Permian Basin	San Andres-Clearfork, Central Basin Platform and Ozona Arch.
4411	49	193	Permian Basin	San Andres-Clearfork, Northwestern and Eastern Shelves.
4412	102	5	Permian Basin	Delaware Sandstones.
4501	4	16	Bend Arch-Fort Worth Basin	Pre-Mississippian Carbonate.
4502	1	26	Bend Arch-Fort Worth Basin	Mississippian Carbonate.
4504	50	1	Bend Arch-Fort Worth Basin	Lower Pennsylvanian (Bend) Sandstone and Conglomerate.
4505	150	51	Bend Arch-Fort Worth Basin	Strawn (Desmoinesian).
4506	12	10	Bend Arch-Fort Worth Basin	Post-Desmoinesian.

Table 9. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in the Permian Basin Province of Region 5.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 8. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
Clastic reservoirs							
4402	17	9.31	9.58	10.18	11.76	14.76	6.96
4404	3	9.30	9.71	10.11	10.86	11.60	6.56
4406	39	8.96	9.53	9.90	13.58	19.36	6.61
4407	13	8.91	9.30	9.60	13.39	18.09	6.08
4409	30	8.67	10.04	11.83	13.93	14.53	7.20
4410	21	9.15	10.72	19.29	19.36	19.65	4.95
4411	49	8.79	9.10	9.50	12.48	19.35	6.38
4412	102	9.10	9.66	9.87	13.48	18.10	6.89
Carbonate reservoirs							
4402	107	12.19	12.94	13.52	16.62	26.94	5.89
4403	58	11.95	12.98	13.40	17.65	25.68	5.43
4404	4	12.10	12.63	15.36	18.12	18.71	5.86
4405	31	12.20	13.00	13.22	13.76	25.04	5.71
4406	111	11.82	12.99	13.33	14.46	26.92	5.91
4407	16	11.84	12.27	12.50	13.03	17.49	5.27
4408	20	12.47	13.01	13.36	15.45	24.88	5.84
4410	164	10.78	14.08	25.42	25.59	25.93	4.52
4411	193	10.70	12.55	13.43	17.31	25.72	5.39
4412	5	12.41	12.45	13.32	19.09	19.55	6.06

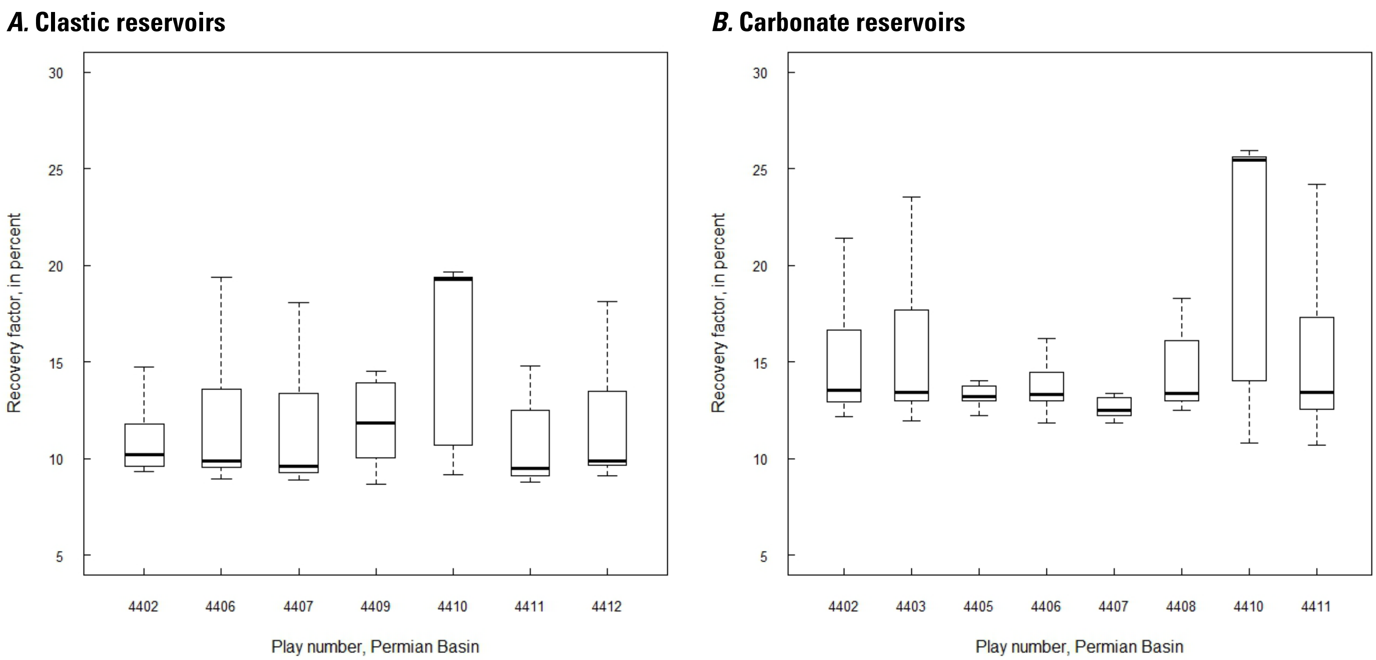

Figure 6. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within the Permian Basin Province of Region 5. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 8. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 10. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in the Bend Arch-Fort Worth Basin Province of Region 5.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 8. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
Clastic reservoirs							
4501	4	9.41	9.46	10.23	12.60	17.51	6.61
4504	50	8.83	9.46	10.28	13.37	18.15	6.20
4505	150	8.48	9.30	9.57	12.77	18.91	5.90
4506	12	8.68	9.46	9.72	12.99	19.24	5.66
Carbonate reservoirs							
4501	16	11.82	12.41	12.70	15.29	18.20	5.56
4502	26	11.39	12.69	15.22	17.62	18.16	5.26
4505	51	11.61	12.30	12.91	17.01	25.55	4.81
4506	10	11.64	12.41	14.67	16.76	17.84	4.46

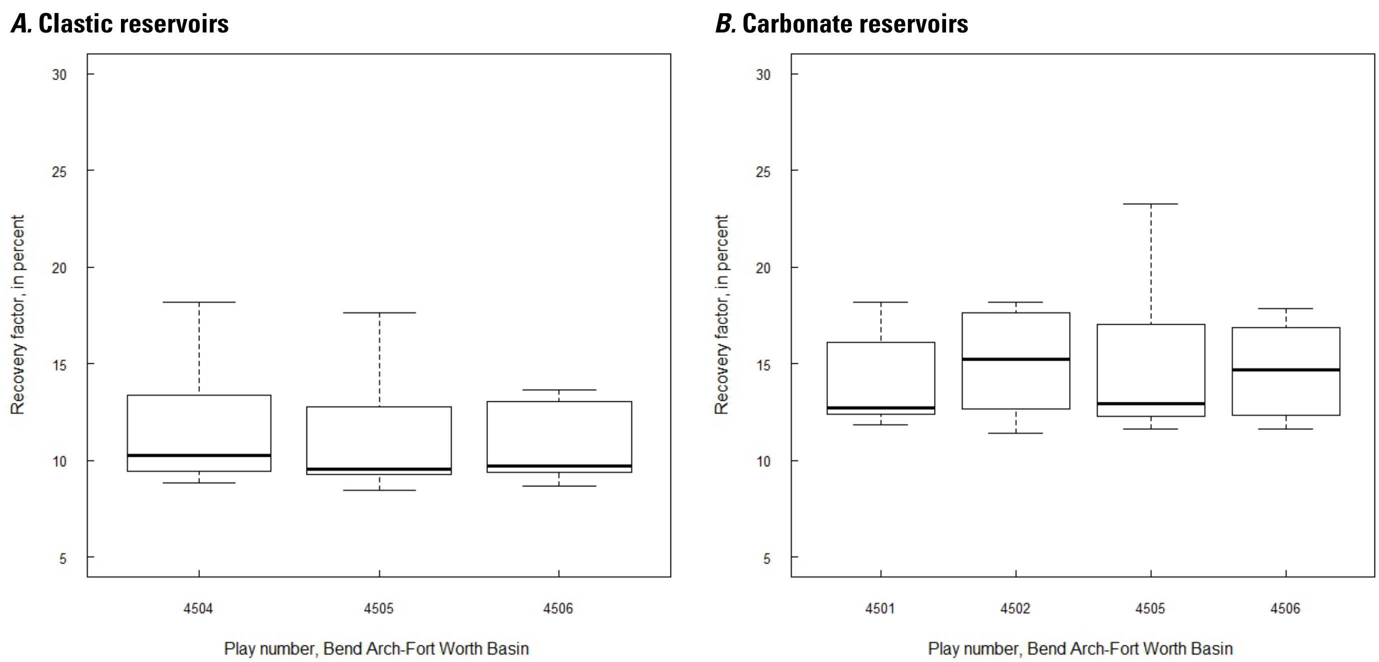

Figure 7. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within the Bend Arch-Fort Worth Basin Province of Region 5. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 8. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 11. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 6, the Gulf Coast Region.

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero; Louis.-Miss. Salt Basins, Louisiana-Mississippi Salt Basins]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
4701	19	–	Western Gulf	Houston Salt Dome Flank Oil and Gas.
4705	–	9	Western Gulf	Lower Cretaceous Carbonate Shelf/Shelf Edge Gas and Oil.
4708	–	1	Western Gulf	Buda Downdip Oil.
4710	8	–	Western Gulf	Woodbine South Angelina Flexure Oil and Gas.
4715	3	–	Western Gulf	Upper Cretaceous Sandstones Fault Zone Oil.
4716	–	1	Western Gulf	Upper Cretaceous Sandstones Maverick Basin Oil.
4719	9	–	Western Gulf	Lower Wilcox Fluvial Oil and Gas
4722	29	–	Western Gulf	Upper Wilcox Shelf-Edge Gas and Oil.
4724	2	–	Western Gulf	Middle Eocene Sandstones Downdip Gas.
4725	11	–	Western Gulf	Middle Eocene Sandstones Updip Fluvial Oil and Gas.
4726	33	–	Western Gulf	Yegua Updip Fluvial-Deltaic Oil and Gas.
4728	2	–	Western Gulf	Jackson Updip Gas and Oil.
4730	5	–	Western Gulf	Vicksburg Updip Gas.
4731	2	–	Western Gulf	Vicksburg Downdip Gas.
4732	1	–	Western Gulf	Frio South Texas Downdip Gas.
4733	49	–	Western Gulf	Frio South Texas Mid-Dip Oil and Gas.
4734	5	–	Western Gulf	Frio Updip Fluvial Gas and Oil.
4735	66	–	Western Gulf	Frio SE Texas/S. Louisiana Mid-Dip Gas and Oil.
4736	18	–	Western Gulf	Frio SE Texas/S. Louisiana Downdip Gas.
4737	9	–	Western Gulf	Hackberry Sandstone Gas and Oil.
4738	32	–	Western Gulf	Anahuac Sandstone Gas and Oil.
4739	1	–	Western Gulf	Lower Miocene Fluvial Sandstone Oil and Gas.
4740	15	–	Western Gulf	Lower Miocene Deltaic Sandstone Gas and Oil.
4741	7	–	Western Gulf	Lower Miocene Slope and Fan Sandstone Gas.
4743	68	–	Western Gulf	Middle Miocene Deltaic Sandstone Gas and Oil.
4745	34	–	Western Gulf	Upper Miocene Deltaic Sandstone Gas and Oil.
4746	1	–	Western Gulf	Plio-Pleistocene Fluvial Sandstone Oil.
4901	6	–	Louis.-Miss. Salt Basins	Piercement Salt Dome Flanks Oil and Gas.
4905	2	–	Louis.-Miss. Salt Basins	Norphlet Salt Basin Oil and Gas.
4910	–	8	Louis.-Miss. Salt Basins	Smackover Alabama/Florida Peripheral Fault Zone Oil and Gas.
4911	–	1	Louis.-Miss. Salt Basins	Smackover Alabama/Florida Updip Oil.
4912	–	31	Louis.-Miss. Salt Basins	Smackover Salt Basins Gas and Oil.
4916	–	10	Louis.-Miss. Salt Basins	Smackover East Texas-Southern Arkansas Fault Zone Oil and Gas.
4917	–	3	Louis.-Miss. Salt Basins	Smackover East Texas-South Arkansas Updip Oil.
4918	5	–	Louis.-Miss. Salt Basins	Haynesville Salt Basins Gas and Oil.
4919	1	–	Louis.-Miss. Salt Basins	Haynesville Updip Alabama-Florida Oil.
4921	15	–	Louis.-Miss. Salt Basins	Cotton Valley Updip Oil.

Table 11. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 6, the Gulf Coast Region.—Continued

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero; Louis.-Miss. Salt Basins, Louisiana-Mississippi Salt Basins]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
4925	12	–	Louis.-Miss. Salt Basins	Hosston Updip Oil.
4926	2	–	Louis.-Miss. Salt Basins	Hosston/Travis Peak Salt Basins Gas.
4928	7	11	Louis.-Miss. Salt Basins	Sligo/Pettet Updip Oil.
4929	–	6	Louis.-Miss. Salt Basins	Sligo/Pettet Salt Basins Gas.
4930	–	13	Louis.-Miss. Salt Basins	Pettet Southern Sabine Uplift Gas and Oil.
4931	–	1	Louis.-Miss. Salt Basins	James Limestone Gas.
4932	25	13	Louis.-Miss. Salt Basins	Glen Rose/Rodessa Updip Oil.
4934	27	–	Louis.-Miss. Salt Basins	Paluxy Updip Oil.
4935	4	–	Louis.-Miss. Salt Basins	Paluxy Downdip Gas.
4936	4	–	Louis.-Miss. Salt Basins	Tuscaloosa Peripheral Fault Zone Oil.
4937	29	–	Louis.-Miss. Salt Basins	Tuscaloosa/Woodbine Structural Oil and Gas.
4938	16	–	Louis.-Miss. Salt Basins	Tuscaloosa Stratigraphic Oil and Gas.
4939	2	–	Louis.-Miss. Salt Basins	Woodbine/Tuscaloosa Sabine Flanks Oil.
4940	3	–	Louis.-Miss. Salt Basins	Eutaw/Tokio Updip Oil.
4945	80	–	Louis.-Miss. Salt Basins	Wilcox Salt Basins Oil.

Table 12. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in the Western Gulf Province of Region 6.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 11. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
			Clastic reservoirs				
4701	19	8.54	8.99	9.22	12.09	20.34	5.18
4710	8	9.11	9.28	9.53	9.70	9.93	6.63
4715	3	8.82	8.93	9.03	11.00	12.97	5.23
4719	9	8.78	8.85	8.95	9.34	12.76	4.86
4722	29	8.69	9.11	9.23	10.20	17.61	6.55
4725	11	8.52	9.00	9.28	9.44	10.59	5.42
4726	33	8.64	8.75	8.86	9.23	16.82	5.58
4730	5	8.60	8.63	8.64	8.64	8.73	5.58
4733	49	8.62	8.92	9.17	9.48	18.87	5.56
4734	5	8.80	9.18	9.22	9.46	9.60	5.20
4735	66	8.30	8.88	9.00	9.22	19.59	5.91
4736	18	8.76	8.96	9.44	10.11	17.34	6.53
4737	9	8.73	8.89	9.16	9.31	10.70	6.03
4738	32	8.71	8.80	8.91	9.07	17.01	5.89
4740	15	8.56	8.87	8.97	9.04	13.97	5.68
4741	7	8.99	9.01	9.02	9.43	9.48	5.30
4743	68	8.52	8.93	9.12	9.33	10.06	6.25
4745	34	8.62	8.83	8.95	9.12	9.46	5.61
			Carbonate reservoirs				
4705	9	12.05	12.43	12.58	13.56	22.76	6.03

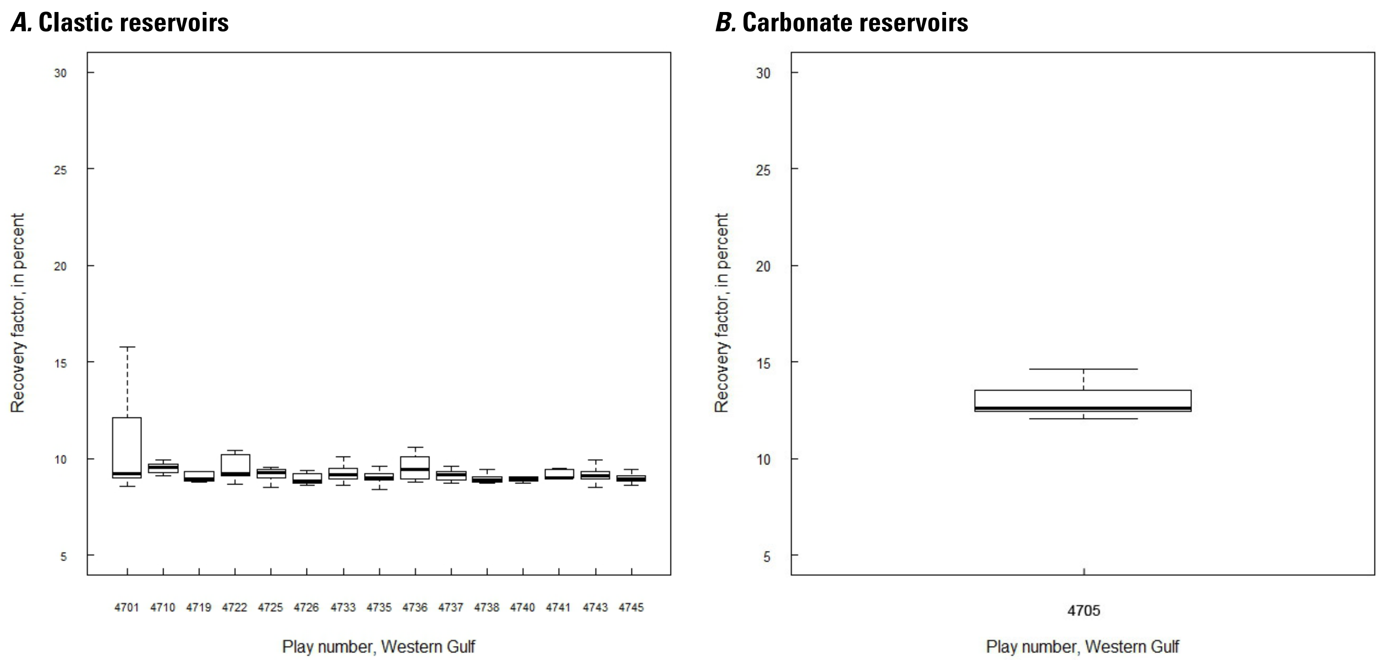

Figure 8. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within the Western Gulf Province of Region 6. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 11. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 13. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in the Louisiana-Mississippi Salt Basins Province of Region 6.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 11. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
			Clastic reservoirs				
4901	6	8.56	9.51	12.48	12.92	17.36	5.62
4918	5	9.06	9.20	9.69	12.75	13.58	5.67
4921	15	9.11	9.41	9.48	11.30	13.72	6.06
4925	12	9.07	9.16	10.34	12.61	17.27	5.44
4928	7	9.29	9.44	9.52	9.78	13.05	6.00
4932	25	8.31	8.99	9.27	9.60	17.91	5.94
4934	27	8.85	9.01	9.29	9.98	17.41	5.51
4935	4	9.04	9.06	9.19	10.24	13.03	6.06
4936	4	9.14	9.57	10.00	11.92	16.84	5.23
4937	29	8.53	9.05	9.34	12.53	17.41	5.63
4938	16	8.94	9.09	12.73	13.00	17.63	5.76
4940	3	8.89	10.12	11.35	13.90	16.46	4.44
4945	80	8.58	8.92	9.12	9.59	18.20	4.98
			Carbonate reservoirs				
4910	8	12.30	12.66	13.10	13.40	24.17	6.80
4912	31	11.76	12.36	12.57	13.64	23.82	5.44
4916	10	11.55	12.15	12.54	12.96	24.09	5.32
4917	3	11.74	11.92	12.11	12.31	12.51	5.12
4928	11	11.43	12.16	12.42	17.35	22.84	4.84
4929	6	12.00	12.98	13.05	16.41	17.84	5.63
4930	13	11.76	12.28	12.55	15.66	23.14	5.26
4932	13	11.13	12.49	13.09	16.84	22.74	4.90

A. **Clastic reservoirs** *B.* **Carbonate reservoirs**

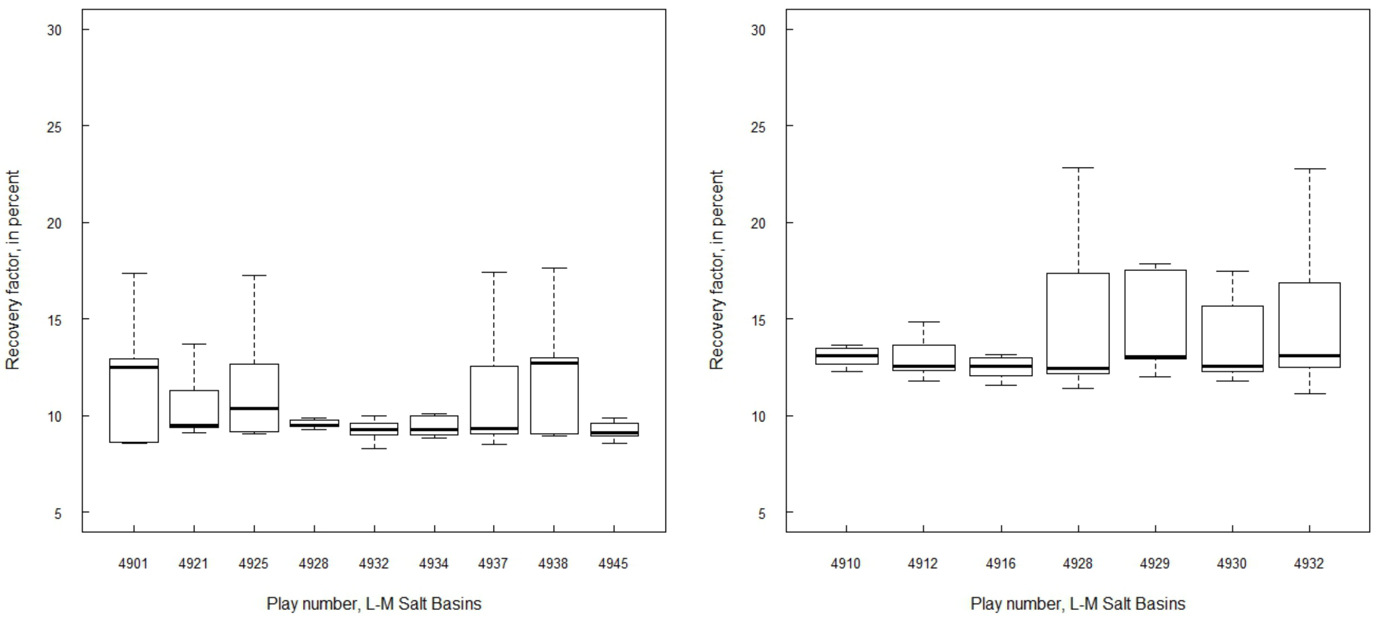

Figure 9. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within the Louisiana-Mississippi (L-M) Salt Basins Province of Region 6. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 11. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 14. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 7, the Midcontinent Region.

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
5304	2	6	Cambridge Arch-Central Kansas Uplift	Mississippian and Devonian.
5305	6	57	Cambridge Arch-Central Kansas Uplift	Pennsylvanian Cyclical Carbonates and Sandstones.
5308	5	4	Cambridge Arch-Central Kansas Uplift	Ordovician.
5309	2	56	Cambridge Arch-Central Kansas Uplift	Early Ordovician/Cambrian Arbuckle.
5501	36	21	Nemaha Uplift	Pre-Woodford Paleozoic.
5503	–	23	Nemaha Uplift	Mississippian.
5504	15	2	Nemaha Uplift	Pennsylvanian-Permian Structural.
5505	35	7	Nemaha Uplift	Pennsylvanian Stratigraphic.
5801	1	1	Anadarko Basin	Deep Structural Gas.
5802	–	1	Anadarko Basin	Uppermost Arbuckle.
5804	1	–	Anadarko Basin	Wichita Mountains Uplift.
5805	3	–	Anadarko Basin	Simpson Oil and Gas.
5809	–	5	Anadarko Basin	Hunton Stratigraphic-Unconformity Gas and Oil.
5810	5	–	Anadarko Basin	Misener Oil.
5812	1	–	Anadarko Basin	Deep Stratigraphic Gas.
5813	2	35	Anadarko Basin	Lower Mississippian Stratigraphic Oil and Gas.
5814	1	26	Anadarko Basin	Upper Mississippian Stratigraphic Gas and Oil.
5815	1	–	Anadarko Basin	Springer Stratigraphic Gas and Oil.
5816	64	–	Anadarko Basin	Morrow Sandstone Gas and Oil Stratigraphic.
5819	14	–	Anadarko Basin	Lower Desmoinesian Stratigraphic Gas and Oil.
5820	–	24	Anadarko Basin	Upper Desmoinesian Oil and Gas.
5821	11	1	Anadarko Basin	Lower Missourian Stratigraphic Oil and Gas.
5822	–	19	Anadarko Basin	Upper Missourian Oil and Gas.
5823	14	–	Anadarko Basin	Lower Virgilian Sandstone Gas and Oil.
5824	–	5	Anadarko Basin	Upper Virgilian Stratigraphic Oil and Gas.
5827	3	–	Anadarko Basin	Washes.
5901	5	9	Sedgwick Basin	Lower Paleozoic Combination Traps.
5902	1	20	Sedgwick Basin	Mississippian Combination Traps.
5903	4	2	Sedgwick Basin	Pennsylvanian Combination Traps.
6001	50	55	Cherokee Platform	Pre-Woodford Paleozoic.
6003	–	5	Cherokee Platform	Mississippian.
6004	12	1	Cherokee Platform	Pennsylvanian Structural.
6005	21	–	Cherokee Platform	Pennsylvanian Stratigraphic.
6101	1	–	Southern Oklahoma	Deep Gas.

Table 14. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 7, the Midcontinent Region.—Continued

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
6102	–	8	Southern Oklahoma	Arbuckle Oil.
6103	14	–	Southern Oklahoma	Simpson Structural Oil.
6104	1	12	Southern Oklahoma	Viola Oil and Gas.
6105	–	4	Southern Oklahoma	Hunton Oil.
6107	2	6	Southern Oklahoma	Misener-Woodford-Sycamore Gas and Oil.
6108	2	–	Southern Oklahoma	Springer Sandstone Oil and Gas.
6109	1	–	Southern Oklahoma	Atokan Sandstone Oil.
6110	12	–	Southern Oklahoma	Desmoinesian Sandstone Oil.
6111	2	–	Southern Oklahoma	Missourian Sandstone Oil and Gas.
6204	1	–	Arkoma Basin	Morrowan Shallow Marine Sandstone and Limestone Gas.
6205	1	2	Arkoma Basin	Arbuckle through Misener Basement Fault and Shelf Gas.

Table 15. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in Region 7, the Midcontinent Region, excluding plays in the Anadarko Basin Province.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 14. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
Clastic reservoirs							
5305	6	8.14	8.72	8.85	8.96	12.23	5.86
5308	5	8.93	9.15	9.24	10.83	12.12	6.22
5501	36	8.78	9.13	9.36	9.69	18.96	5.89
5504	15	8.71	9.61	9.85	10.10	13.73	7.45
5505	35	8.84	9.55	9.65	11.42	17.72	4.86
5901	5	9.09	9.66	10.24	10.67	19.38	6.01
5903	4	8.83	8.86	8.93	8.99	9.00	5.89
6001	50	8.31	8.95	9.13	9.31	17.65	5.80
6004	12	8.71	8.88	9.03	9.25	12.54	5.65
6005	21	8.78	8.91	9.09	12.15	13.18	5.88
6103	14	8.98	9.62	12.80	13.37	20.45	5.35
6110	12	8.84	9.25	9.47	12.73	12.83	6.42
Carbonate reservoirs							
5304	6	11.52	12.21	16.80	21.58	22.08	4.49
5305	57	10.40	11.35	14.91	16.83	22.59	4.71
5308	4	12.96	13.50	14.12	14.66	14.98	4.82
5309	56	10.03	14.76	15.52	16.88	22.30	4.55
5501	21	11.67	12.34	14.84	17.18	25.29	5.07
5503	23	11.45	12.66	13.42	15.36	17.70	4.76
5505	7	11.91	12.46	12.55	12.65	12.69	4.19
5901	9	21.68	22.41	22.69	23.04	23.44	4.00
5902	20	11.05	11.66	12.43	22.53	24.22	5.24
6001	55	11.32	12.66	13.45	13.78	22.84	4.73
6003	5	11.47	12.33	12.73	16.68	16.87	4.60
6102	8	11.44	11.90	12.07	12.35	12.88	4.81
6104	12	11.80	11.82	12.02	12.24	16.67	4.16
6105	4	12.54	12.55	12.57	12.65	12.86	5.59
6107	6	11.91	12.20	12.68	13.06	13.38	5.54

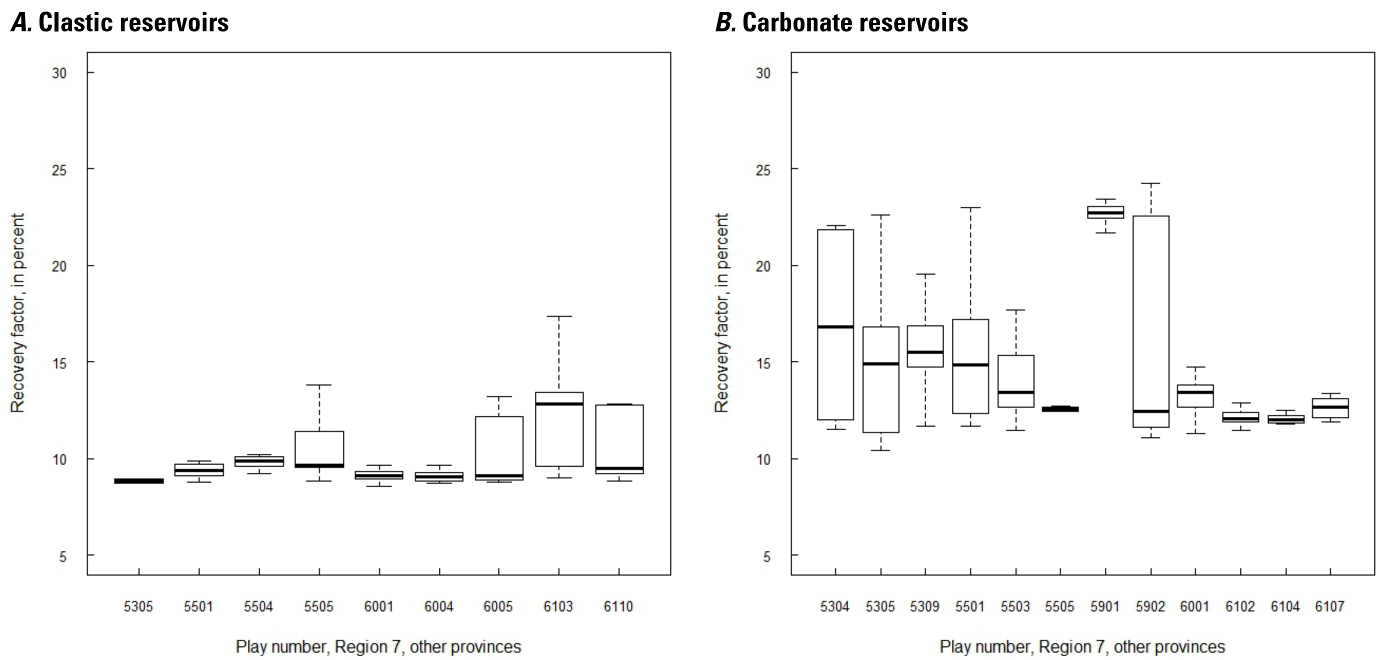

Figure 10. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within Region 7, the Midcontinent Region, excluding plays in the Anadarko Basin Province. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 14. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 16. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in the Anadarko Basin Province of Region 7.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 14. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
			Clastic reservoirs				
5805	3	9.55	9.65	9.74	11.76	13.79	6.31
5810	5	9.48	9.52	9.67	9.74	11.56	6.86
5816	64	8.57	9.31	9.55	12.86	13.91	6.07
5819	14	8.99	9.41	9.59	12.35	19.30	6.24
5821	11	9.70	9.83	10.02	10.78	14.15	7.46
5823	14	9.40	9.64	9.71	9.92	14.58	7.06
5827	3	9.31	9.54	9.77	11.91	14.05	7.68
			Carbonate reservoirs				
5809	5	11.97	12.22	12.65	17.87	18.10	4.39
5813	35	11.79	12.30	16.60	22.14	23.04	4.90
5814	26	11.20	12.90	13.88	14.59	23.64	5.48
5820	24	11.36	12.73	13.68	14.70	22.03	5.34
5822	19	11.31	11.72	11.91	12.40	14.91	5.19
5824	5	11.57	12.54	13.88	13.97	14.42	5.57

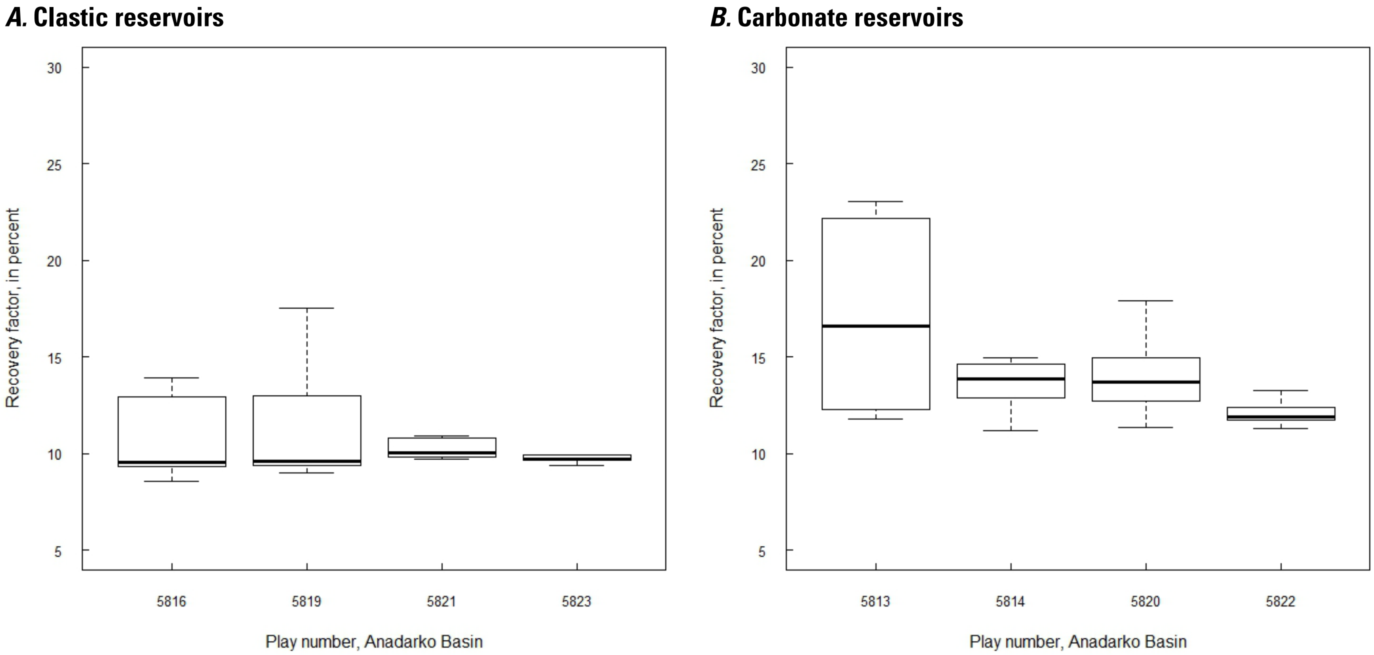

Figure 11. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from (*A*) clastic and (*B*) carbonate oil reservoirs in plays within the Anadarko Basin Province of Region 7. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 14. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

Table 17. Numbers of clastic and carbonate oil reservoirs that are candidates for the application of a miscible CO_2-EOR method in plays of Region 8, the Eastern Region.

[Candidate reservoirs must have permeability values of at least 2 millidarcies, a net pay at least 5 feet thick, and at least 5 million barrels of original oil in place. Petroleum province boundaries and codes are shown in figure 1; province codes are the first 2 digits of the play numbers. CO_2-EOR, carbon dioxide enhanced oil recovery; dash (–), zero]

Play number	Number of oil reservoirs that are candidates for CO_2-EOR		Province name	Play name
	Clastic	Carbonate		
6301	–	27	Michigan Basin	Anticline.
6307	–	31	Michigan Basin	Northern Niagaran Reef.
6308	–	9	Michigan Basin	Southern Niagaran Reef.
6311	–	3	Michigan Basin	Trenton-Black River.
6401	3	10	Illinois Basin	Illinois Basin-Post-New Albany.
6402	–	4	Illinois Basin	Illinois Basin-Hunton.
6404	–	2	Illinois Basin	Illinois Basin-Middle and Upper Ordovician Carbonate.

Table 18. Distributions of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and the median net CO_2 utilization for plays in Region 8, the Eastern Region.

[Estimates were made by using the CO_2 Prophet simulator for candidate oil reservoirs. Play names and numbers are in table 17. Only plays containing at least three candidate reservoirs by lithology type are shown here. Recovery factors are in percent, and the median net CO_2 utilization is in thousands of cubic feet of CO_2 per barrel of produced oil at the surface (mcf/bbl)]

Play number	Number of oil reservoirs	Recovery factor (percent)					Median net CO_2 utilization (mcf/bbl)
		Minimum	1st quartile	Median	3d quartile	Maximum	
Clastic reservoirs							
6401	3	8.76	8.81	8.86	9.05	9.24	5.69
Carbonate reservoirs							
6301	27	11.73	12.60	13.22	15.99	24.52	5.51
6307	31	12.64	13.30	13.58	19.54	24.83	6.73
6308	9	11.85	12.16	12.59	17.16	23.91	5.38
6311	3	12.53	14.46	16.39	18.81	21.23	4.98
6401	10	11.35	11.67	11.79	12.32	22.51	4.92
6402	4	11.83	11.91	12.15	12.40	12.52	5.19

Carbonate reservoirs

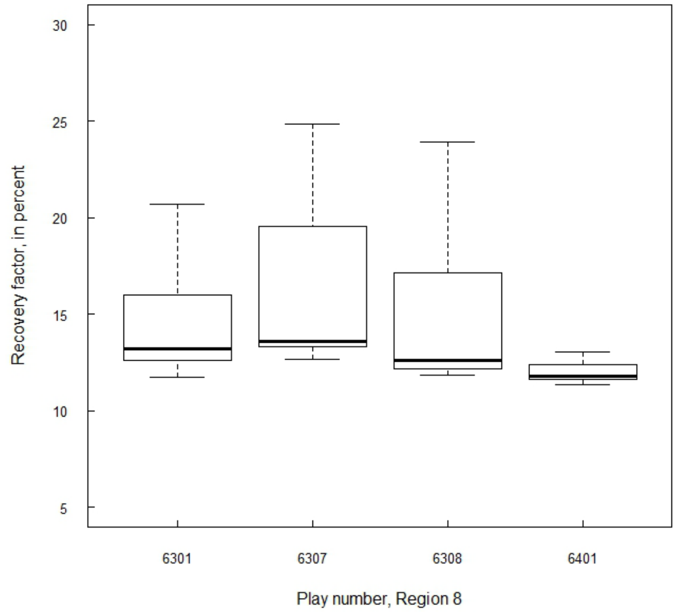

Figure 12. Boxplots of recovery factors for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method from carbonate oil reservoirs in plays within Region 8, the Eastern Region. Estimates were made by using the CO_2 Prophet simulator for candidate reservoirs. Play names and numbers are in table 17. Only plays containing at least six candidate reservoirs by lithology type have recovery factors plotted here.

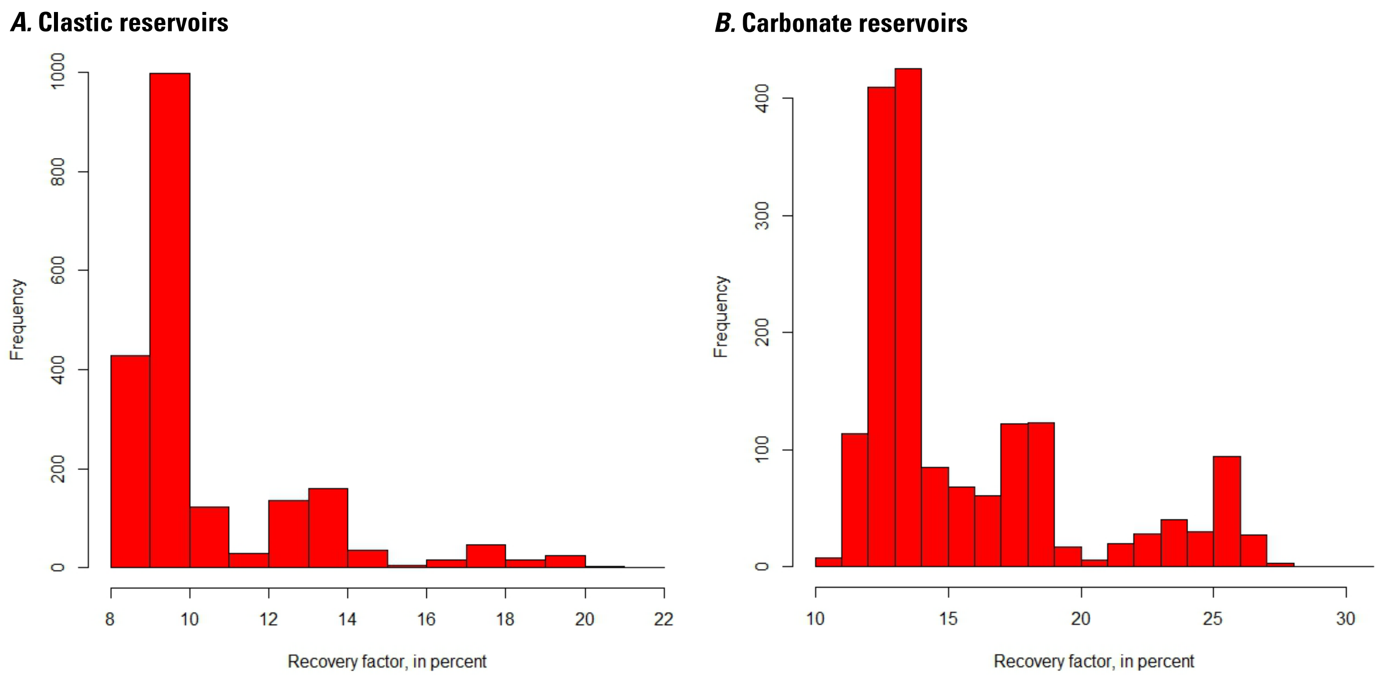

Figure 13. Histograms representing the distribution of recovery factors for (*A*) 2,018 clastic and (*B*) 1,681 carbonate conventional oil reservoirs in the conterminous United States. Recovery factors are for technically recoverable oil that might be produced by use of a miscible carbon dioxide enhanced oil recovery (CO_2-EOR) method and were computed with the CO_2 Prophet simulator.

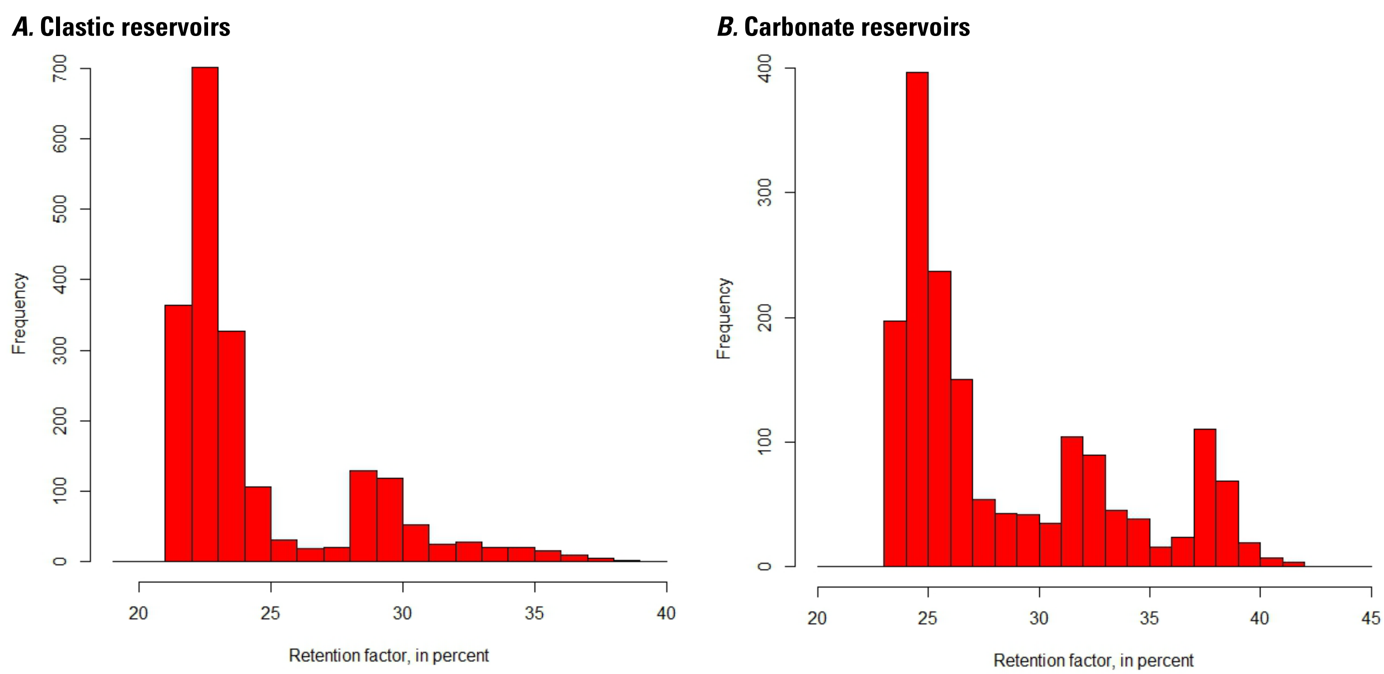

Figure 14. Histograms representing the distribution of CO_2 retention factors for (*A*) 2,018 clastic and (*B*) 1,681 carbonate conventional oil reservoirs in the conterminous United States. Retention factors were computed from the results of miscible carbon dioxide enhanced oil recovery (CO_2-EOR) simulations with the CO_2 Prophet simulator.

Attanasi and Freeman—**Play-Level Distributions of Estimates of Recovery Factors for a Miscible CO_2-EOR Method**—Open-File Report 2015–1239

ISSN 2331-1258 (online)
http://dx.doi.org/10.3133/ofr20151239