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Updates to the EIA Eagle Ford Play Maps

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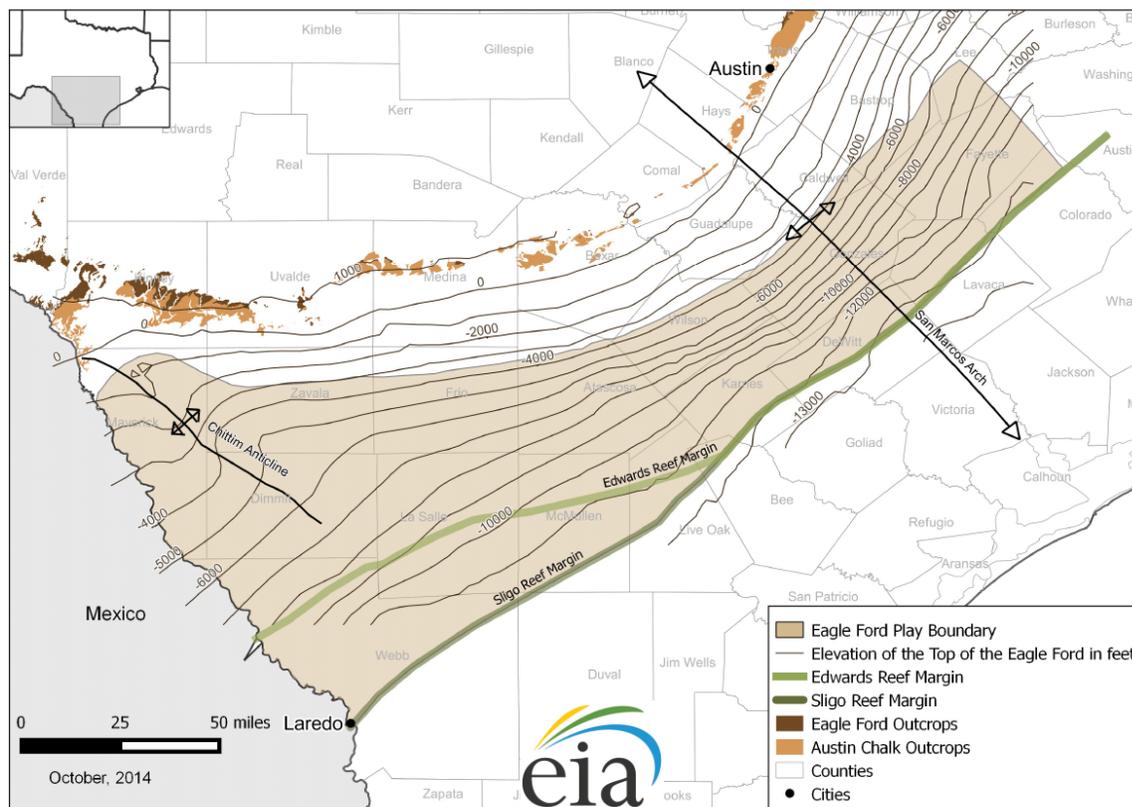
Introduction

EIA is adding and updating geologic information and maps of the major tight oil and shale gas plays. This document outlines updated information and maps for the Eagle Ford play in southwest Texas. The geologic elements characterized and updated since the [2010 Eagle Ford Shale Play map](#) include contoured elevation of the top of formation (structure), contoured thickness (isopach), major structures and tectonic features (regional faults and folds etc.), play boundaries, well locations and gas-to oil ratios of wells producing from January 2000- June 2014.

These geologic elements are documented and illustrated as a series of maps. The Eagle Ford play map consists of layers of geologic and production information that can be published either as separate thematic maps (such as Figure 1) or as a single map with interactive layers. Data sources include DrillingInfo Inc. (DI, a commercial oil and gas well database), the U.S. Geological Survey, the Bureau of Economic Geology, the Texas Natural Resources Information System (a division of the Texas Water Development Board), peer-reviewed research papers, and academic theses.

Note: EIA's access to well level-data is limited, and EIA is working on expanding its well-level data to include well-log information. Additional map layers will be added as additional geologic data (such as porosity) becomes available.

Figure 1. Eagle Ford Play, Western Gulf Province, Texas



Sources: U.S. Energy Information Administration, DrillingInfo, Inc., Texas Natural Resources Information, U.S. Geological Survey, Texas Bureau of Economic Geology.

The Eagle Ford Play boundaries

The Eagle Ford Play (Figure 1) has four major boundaries: 1) The international border to the west, 2) a northern boundary above a minimum subsea depth of 3650 feet to intersect the top of the upper Eagle Ford formation in Frio County and counties east, and above minimum depths in Maverick and Zavala counties, ranging from 650 to 2900 feet, 3) a southern boundary that traces the Early Cretaceous Sligo Reef Margin, and 4) a northeastern boundary where the lower Eagle Ford (the primary target for drilling and completion) thins and grades into more silica-rich units of the Pepper Shale of the East Texas Basin (Hentz et al., 2014).

EIA's analysis of the Eagle Ford Play is truncated at the international border, because EIA does not have well-level production and geologic data from the Eagle Ford formation on the Mexican side of the border.

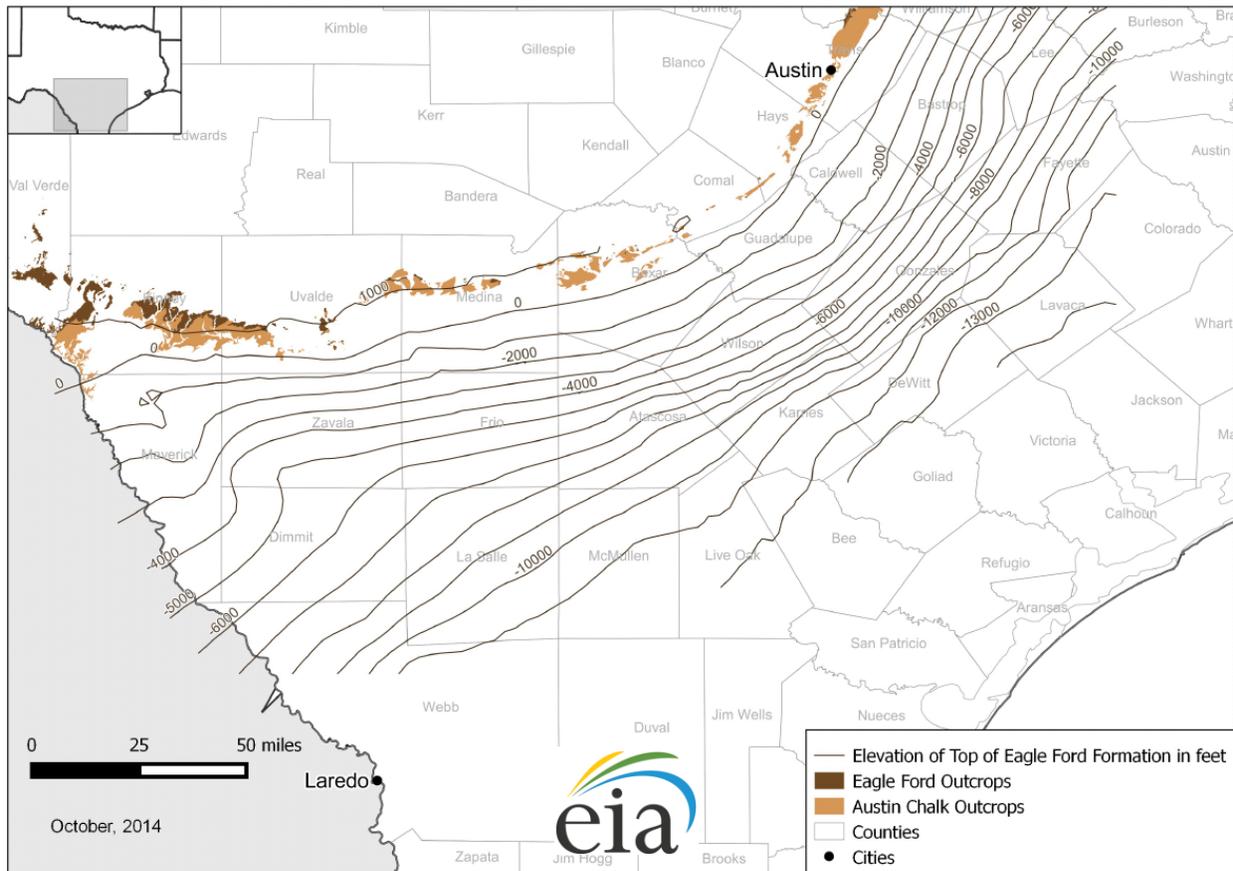
The northern boundary of the Eagle Ford Play is defined according to where the oil window ends and the immature area begins, according to a study that used thermal modeling calibrated to published vitrinite reflectance (%Ro) data (Cardneaux, 2012). The limits of the oil window correlate to a subsea structure depth of about 650 feet in Maverick county, about 2900 feet in Zavala county, and about 3650 feet in Frio county. The change in depth in relation to maturity reflects the amount of differential subsidence within the Maverick basin and subsequent uplift and erosion along the Chittim Anticline. The limit of the oil window east of Frio county is assumed to correlate with a subsea depth of approximately 3650 feet.

The northeastern Eagle Ford play boundary is defined by the transition from the carbonate-rich lower Eagle Ford group to the silica-rich Pepper Shale formation. The lower Eagle Ford formation is thickest in the Maverick Basin and thins to a minimum over the San Marcos Arch. Northeast of the San Marcos Arch the lower Eagle Ford grades into the Pepper Shale. Northeast of the Eagle Ford play, operators are targeting low-permeability sandstone beds within the Pepper Shale and Woodbine Group in a region referred to as the "Eaglebine" play (Hentz et al., 2014).

Contoured elevation of the top surface of Eagle Ford formation

Contoured elevation maps of the top surface of a geologic formation (also called structure maps) constructed from point elevation data (from wells and/or outcrops) provide the third dimension for characterizing depth or elevation of a reservoir on an otherwise two-dimensional map. The elevation map for the top of the Eagle Ford formation (Figure 2) was constructed from both subsurface well data (DrillingInfo Inc.) and above ground outcrop elevation data (from the Texas Natural Resources Information System and the U.S. Geological Survey). The Eagle Ford formation is divided into upper and lower units, and the top of the lower unit is considered the best proxy for the source rock; however, due to a lack of density and distribution of the depth to the top of the lower Eagle Ford formation, this map represents an approximation of the elevation of the top of the upper Eagle Ford unit. For a more detailed study that separates the depth of the the upper and lower Eagle Ford formation see [Hentz and Ruppel \(2011\)](#).

Figure 2. Elevation contours of the top of the Eagle Ford formation

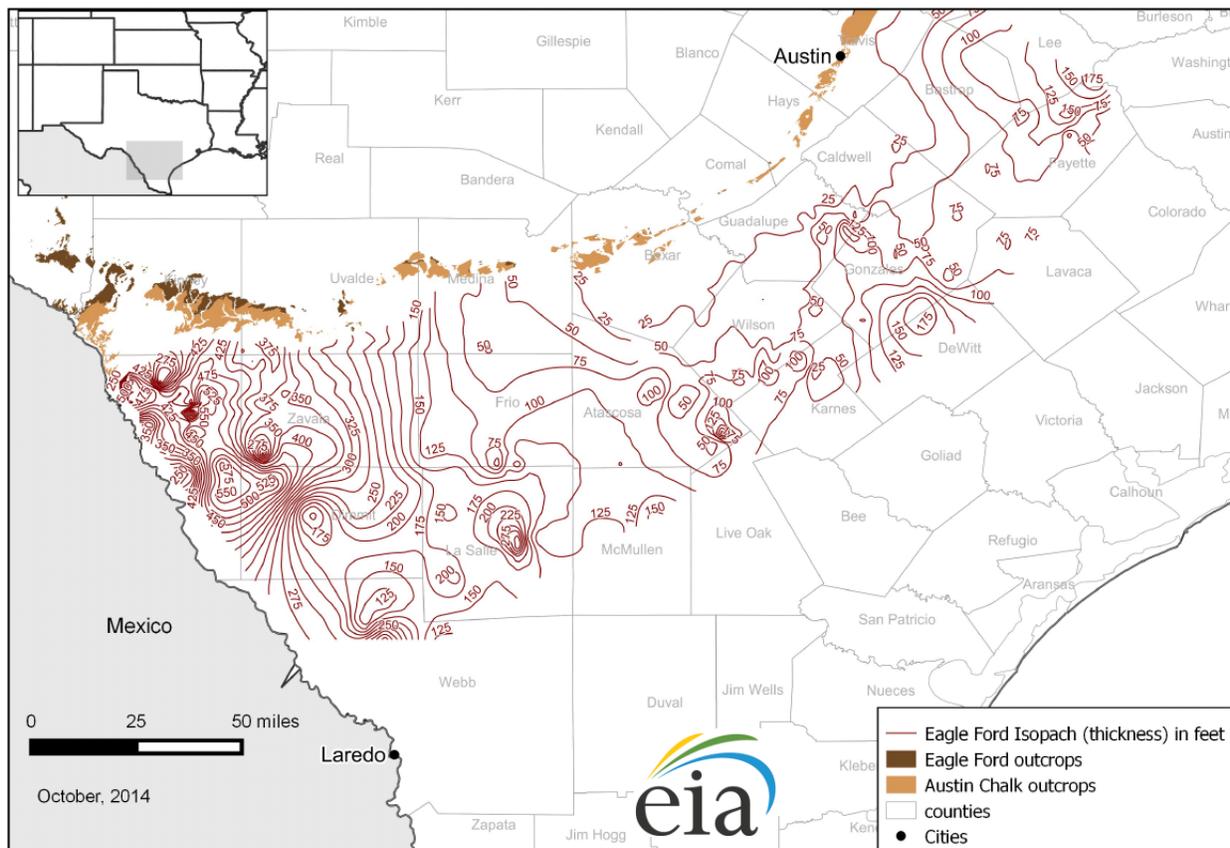


Sources: U.S. Energy Information Administration, Drilling Info, Inc., Texas Natural Resources Information, and U.S. Geological Survey.

Contoured thickness of the Eagle Ford formation (isopachs)

Formation/ reservoir thickness maps (isopachs) provide rough estimates of the thickness of reservoirs. Thickness can be used to calculate resource volumes, such as oil or gas in place estimates, in combination with reservoir information such as porosity and reservoir pressure. The thickness contour maps for the Eagle Ford formation (Figure 3) were constructed from subsurface point thickness data from individual well records (from DrillingInfo Inc.) that include both depth to the top and the base of the Eagle Ford formation. For a more detailed study that separates the upper and lower Eagle Ford units see Hentz and Ruppel (2011).

Figure 3. Thickness contours of the Eagle Ford formation



Sources: U.S. Energy Information Administration, Drilling Info, Inc., Texas Natural Resources Information.

Major geologic, structural and tectonic features relevant to the Eagle Ford play

Summary of Eagle Ford geology

The Eagle Ford shale is a hydrocarbon-bearing, Late Cretaceous formation that was deposited in a marine continental shelf environment. The Eagle Ford formation consists of organic-rich calcareous-mudrock with mineralogy ranging from 40-90% carbonate minerals, 15-30% clay, and 15-20% silica (quartz). The total-organic-carbon content (TOC) ranges from 2-12%, thermal maturity (%Ro) 0.45-1.4%, API gravity 28-62°, porosity 8-12%, and pressure gradient 0.5-0.8+ (psi/ft) (Za Za Energy, 2013). The formation is divided into two units: an upper unit, characterized by interlayered light and dark gray calcareous mudrock deposited during a regressive interval (sea level falling), and a lower unit of mostly dark gray mudstone deposited during a transgressive interval (from rises in sea levels). The Eagle Ford sits above the Buda Limestone and unconformably below the Austin Chalk (Parra et al., 2013).

Structural and tectonic features

The structural and tectonic features that influenced the depositional extent, depth, and thickness of the productive and prospective regions of the Eagle Ford formation are included on the map in Figure 4. The extent of the Eagle Ford formation and variations in its thickness and stratigraphy are in large part constrained by regional tectonic features, including the Maverick Basin, the San Marcos Arch, the Stuart City and Sligo shelf Margin, and the East Texas Basin (Hentz and Ruppel, 2011; Hentz et al., 2014).

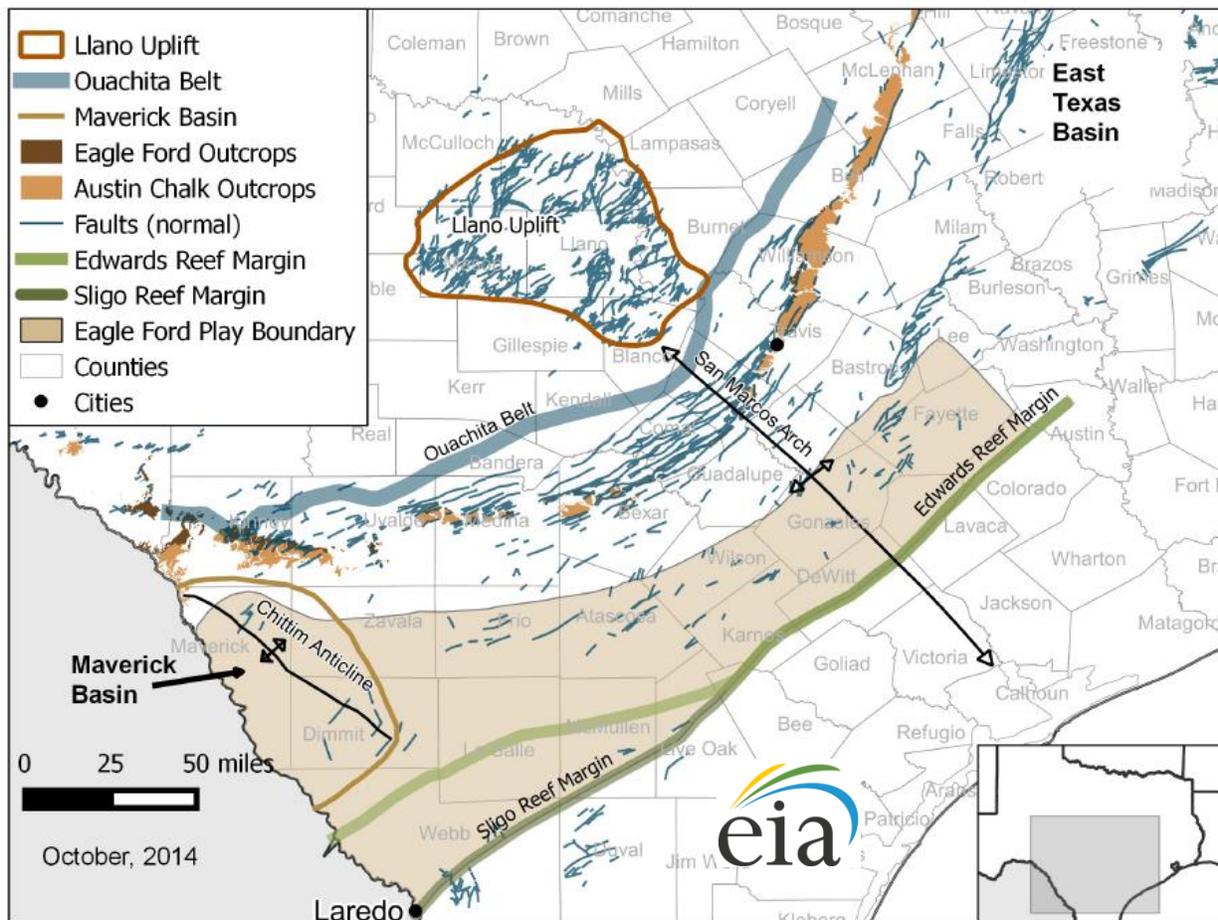
The Eagle Ford formation is thickest in the Maverick Basin and thins to a minimum in the San Marcos Arch region. The Eagle Ford formation continues into the southwest part of the East Texas Basin as a combination of the Maness and Eagle Ford Group facies and grades into coarser sandstone units of Woodbine to the east (Hentz and Ruppel, 2011).

The organic rich carbonate mudrock of the lower Eagle Ford, the primary target of the Eagle Ford play, grades into the more silica-rich Pepper Shale northeast of the San Marcos Arch. The Pepper Shale was deposited in the East Texas Basin and consists of distal deltaic facies that formed on the western edge of the sandstone-rich fluvial-deltaic Woodbine Group (Hentz et al., 2014). Within the Pepper Shale, discontinuous low-permeability sandstone layers are the primary target for drilling and completion (Hentz et al. 2014). Depths of the southeast dipping Eagle Ford range from outcrops to 17, 000 feet at the Stuart City shelf margin. The depth gradients show greatest variation on the flanks and crest of the San Marcos Arch (Figure 1).

Structures that pre-date deposition of the Eagle Ford formation include the Permian-Pennsylvanian Ouachita Belt--a zone of uplift that formed when the continents (Africa, North and South America) collided to form Pangea (Condon and Dyman, 2006). The San Marcos Arch, also formed during Permian-Pennsylvanian compression, forms a broad regional arch over which sediments of the Eagle Ford formation were deposited and are thinnest. The Edwards and Sligo Reef Margins are Early Cretaceous continental shelf edge reefs (Condon and Dyman, 2006) that pre-date the Eagle Ford deposition, but that mark the edge of the Late Cretaceous continental shelf marine environment that characterizes the

most prospective region of the Eagle Ford shale. The Sligo Reef Margin is considered the southern limit of the Eagle Ford play. Structures that post-date deposition of the Eagle Ford formation include the Chittim anticline (part of a series of folds and faults interpreted to have formed during the late Cretaceous to Tertiary), and related Laramide compression (a regional convergent tectonic event) (Condon and Dyman, 2006).

Figure 4. Major structural and tectonic features in the region of the Eagle Ford play



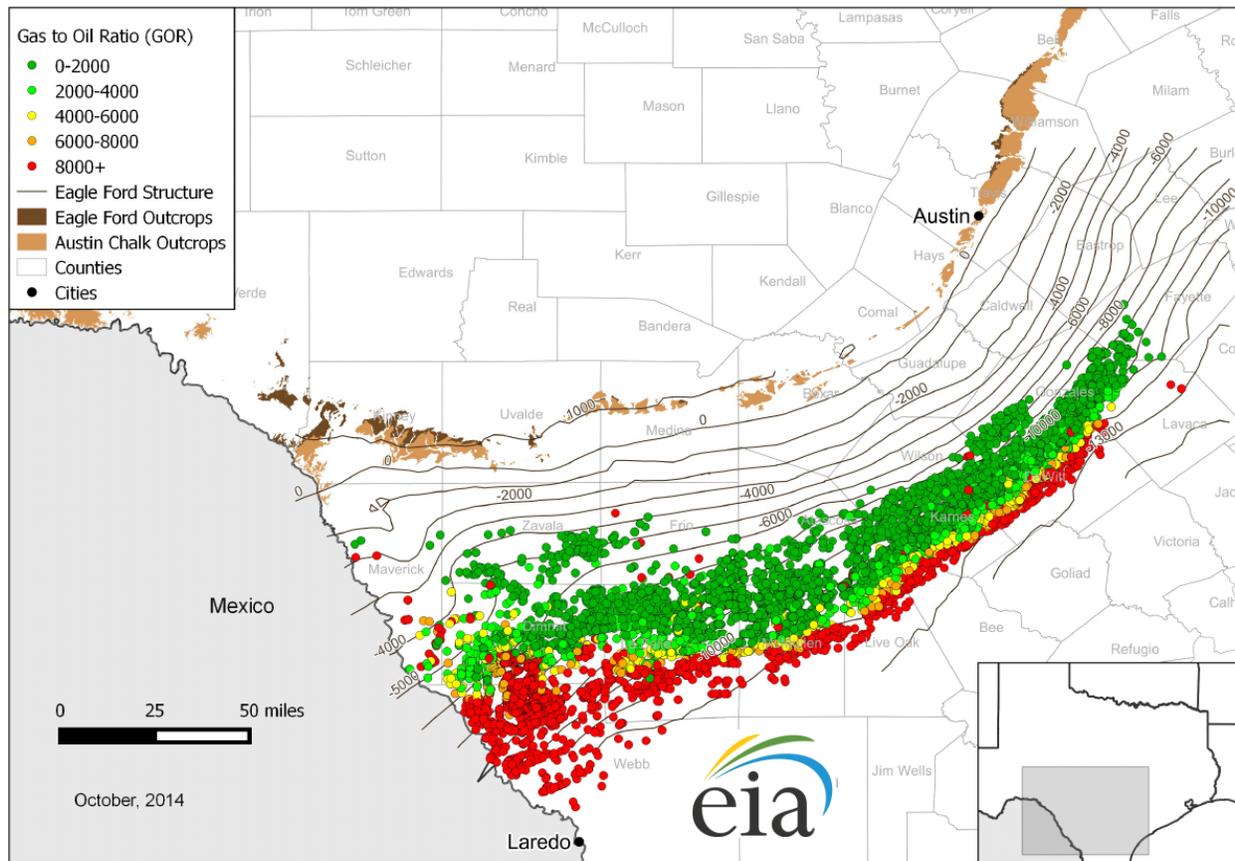
Sources: U.S. Geological Survey (Condon and Dyman, 2006), Bureau of Economic Geology (Hentz and Ruppel, 2011)

Location and initial gas-to-oil ratios of wells producing from the Eagle Ford reservoir (January 2000- June 2014)

Figure 5 shows the distribution of production across the play in terms of initial Gas-to-Oil Ratios (GORs). Most wells now being drilled for hydrocarbons produce a mixture of oil and natural gas. Relatively high oil prices and low natural gas prices make the oil-rich portions of reservoirs more desirable for production, and therefore increasingly the targets for well drilling. The 2010 Eagle Ford map (Figure 6) defined the oil, wet gas, and dry gas “windows” of the play.

The mixture of oil and natural gas is shown for a particular formation by mapping initial GORs (the ratio of natural gas that a well produces to oil for the second through fourth contiguous producing months, expressed as cubic feet per barrel—cf/bbl). In Figure 5, high initial GOR/gas-rich wells of the Eagle Ford Play are shown in orange and red along the southern edge of the play, and lower initial GORs/oil-rich wells are shown in green along the northern portion. Gas-to-Oil Ratios are illustrated using colored point data in the map in Figure 6. The distribution of initial GORs from Eagle Ford play wells generally corresponds to the depth of the reservoir. Deeper wells (up to 15,000 feet) to the southeast have higher initial GORs, or a relatively greater share of natural gas, while the shallower wells to the northwest (below 6,000 feet) have lower initial GORs, or a relatively greater share of oil. In the eastern half of the play, the wells that intersect the reservoir between 5,000 and 12,000 feet depth have initial GORs of 6000cf/bbl or less (producing more oil relative to gas). The western half of the play includes a wider depth distribution of wells, intersecting the formation from as deep as 14,000 feet to as shallow as 2,000 feet, and has initial GORs of 0 to 6000cf/bbl or higher (producing more gas relative to oil).

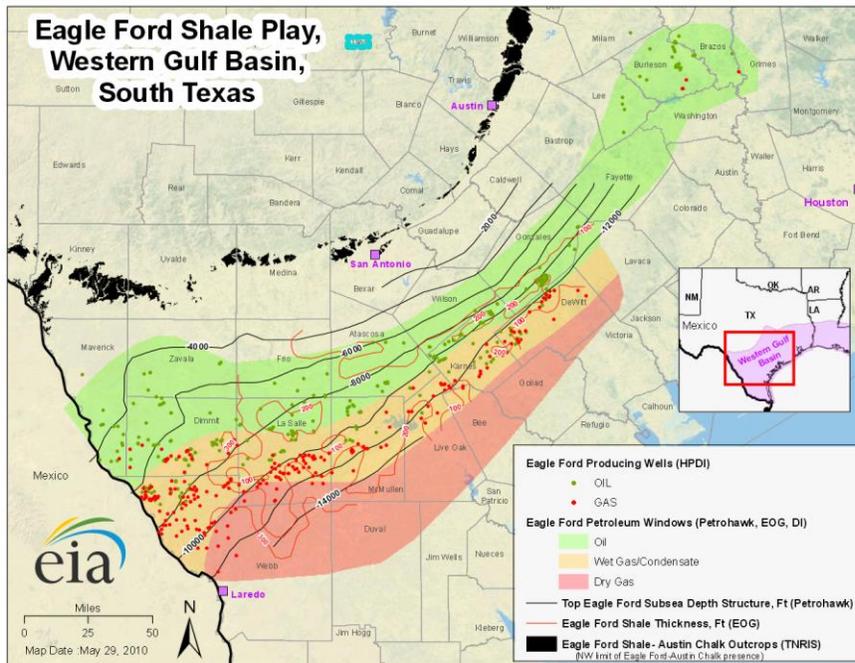
Figure 5. Initial gas-to-oil ratios of Eagle Ford wells (January 2000 – June 2014)



Source: U.S. Energy Information Administration and Drillinginfo Inc., September 2014.

Note: EIA calculates the initial gas-to-oil ratio for each well using the second through fourth contiguous months of liquid and/or gas production. The first month of production may not represent full production and is, thus, not included in the initial GOR calculation.

Figure 6. EIA 2010 Eagle Ford Play Map



Source U.S. Energy Information Administration, DrillingInfo, Inc.

Animated time series of monthly production by location, GOR, and BOE (2009-2013)

In November of 2011, EIA published an animation of Eagle Ford monthly production from 2006–2010 in a [Today in Energy article on the EIA website](#). In February of 2014, an updated version of the Eagle Ford animation was published in [Today in Energy](#) using monthly production data from 2009–2013. The majority of Eagle Ford play wells began production in 2009 or later, as shown in the [animation](#), which displays both the monthly GORs and production of total hydrocarbons in barrels of oil equivalent (BOE). This animation was created using SAS JMP with data from DrillingInfo Inc.

Acknowledgments

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