

# **Evidence Some Oil Accumulations in the Woodford Formation and the Meramec Formation Received an Additional Charge of Very Dry Thermal Gas\***

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Editor's note: Please refer to closely related article [Search and Discovery Article #41845 \(2016\)](#)

[http://www.searchanddiscovery.com/documents/2016/41845kornacki/ndx\\_kornacki.pdf](http://www.searchanddiscovery.com/documents/2016/41845kornacki/ndx_kornacki.pdf)

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## **Abstract**

Do oil or natural gas migrate into and charge kerogen or matrix porosity in mudrock reservoirs? Those reservoirs typically are so impermeable that most of the oil or gas they contain probably was generated by indigenous kerogen: i.e., they were not generated by other source-rock beds and then migrated into them. This implies that dry gas generated at VR >1.5 will not be found in most mudrock reservoirs containing oil-prone kerogen that only has reached the oil window (VR <1.2). The Woodford Formation is an excellent oil-prone source rock in the SCOOP area of the Anadarko Basin and in the nearby Arkoma Basin, where it is being developed as a shale-oil reservoir or a wet gas-shale reservoir (depending on its level of thermal maturity). Oil produced from the overlying Meramec Formation in the STACK area of the Anadarko Basin probably was generated by Woodford kerogen as well. The C isotopic composition of methane through n-pentane in solution gas samples or free gas samples collected from most wells completed in Woodford or Meramec reservoirs is consistent with the thermal maturity of Woodford source rocks at the well locations. But the C isotopic composition of methane is ~3-4 per mil heavier than expected in a Meramec solution gas sample collected from one well in the STACK area, a Woodford free gas sample collected from one well in the SCOOP area, and a Woodford free gas sample collected from one well in the Arkoma Basin where crude oil dropped below its bubble point during basin uplift. In addition, the abundance of saturate and aromatic compounds in the C15+ fraction of “condensates” collected from Woodford gas wells where anomalously-heavy methane also occurs indicates the liquid HC

actually is crude oil that evaporated into undersaturated natural gas, and the abundance of steranes and diamondoids in the Arkoma Basin sample indicate it is a mixture of native oil and severely-cracked oil. These observations indicate an additional charge of thermal gas containing isotopically-heavy methane migrated into some Woodford and Meramec reservoirs. Natural gas samples with isotopically-heavy methane do not contain isotopically-heavy ethane or propane, indicating the additional gas charge consisted almost entirely of methane. The very dry gas charge containing isotopically-heavy methane probably was generated by very mature Woodford source-rock beds at VR >2.0, or by older source-rock beds in the Anadarko Basin and the Arkoma Basin that are not well characterized.

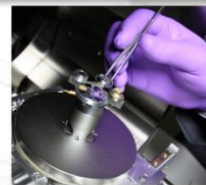
# HIGHER STANDARDS

## Evidence Some Oil Accumulations in the Woodford Formation and the Meramec Formation Received An Additional Charge of Very Dry Thermal Gas

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*We thank Newfield Exploration Company  
for permission to present this talk*



# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## Talk Outline

Introduction: Unconventional oil and gas reservoirs in the Anadarko Basin and the Arkoma Basin.

Woodford Source Rocks: Type/thermal maturity of kerogen.

Maturity of Woodford/Meramec Oils and Condensates: Abundance of SARA compounds.

Maturity of Woodford/Meramec Gas Samples:  
C isotopic composition of propane, ethane, and methane.

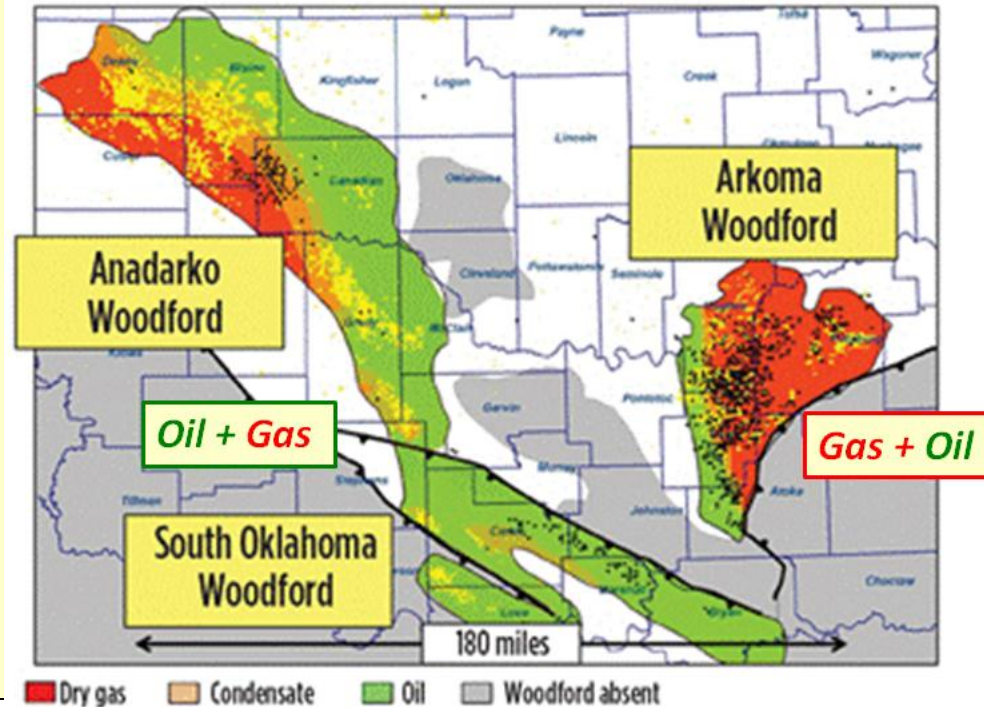
Observation and Conclusions

# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## Introduction

Type and thermal maturity of indigenous kerogen controls the type, amount, and composition of oil and gas pools.

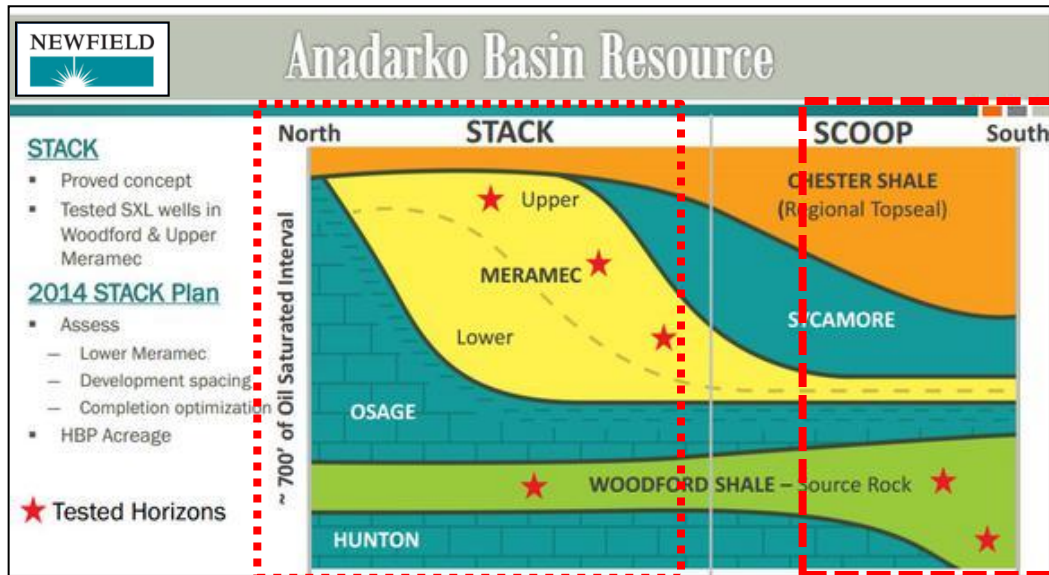
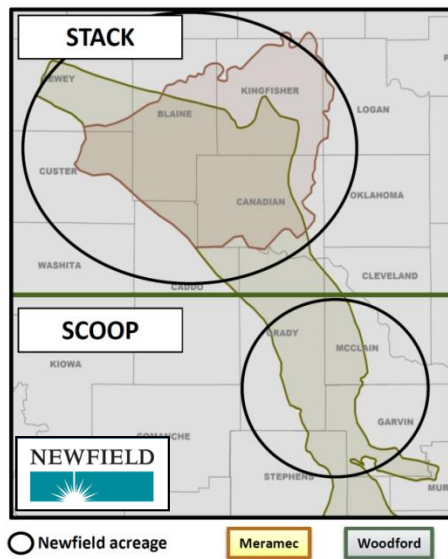
Most mudrock reservoirs are too impermeable ( $k_{air} \approx 100\text{-}1,000\text{ nd}$ ) for oil/gas to migrate into matrix porosity (i.e., seals).



# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## Woodford and Meramec Shale Plays: SCOOP and STACK Areas of the Anadarko Basin, Oklahoma

Newfield is developing: (1) Woodford oil- and gas-shale reservoirs in the SCOOP area of the Anadarko Basin; and (2) Meramec and Woodford oil-shale reservoirs in the STACK area.



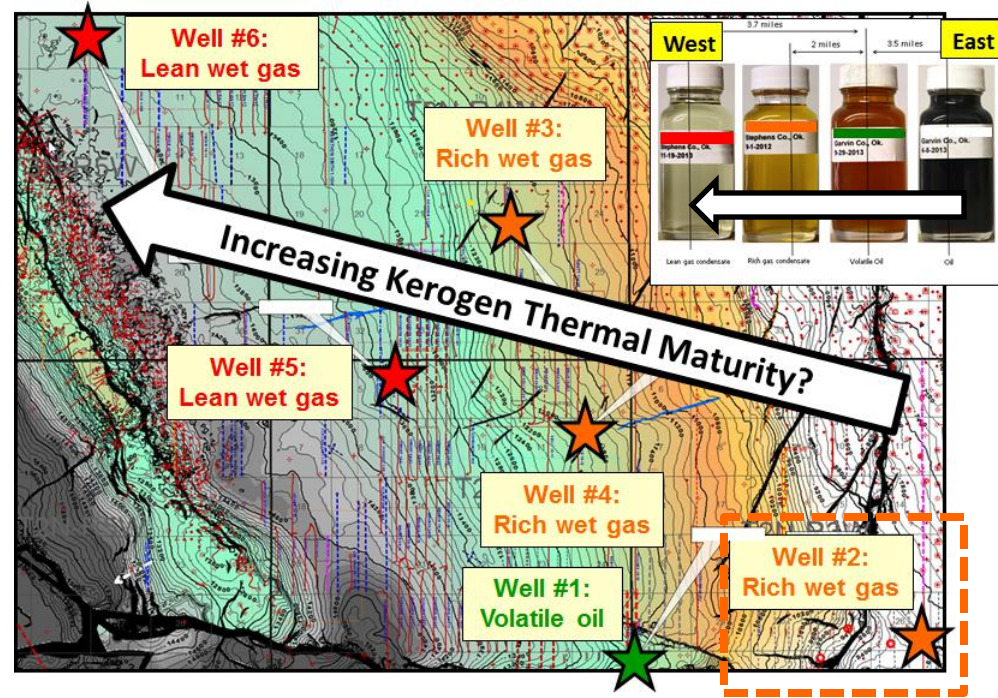


# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

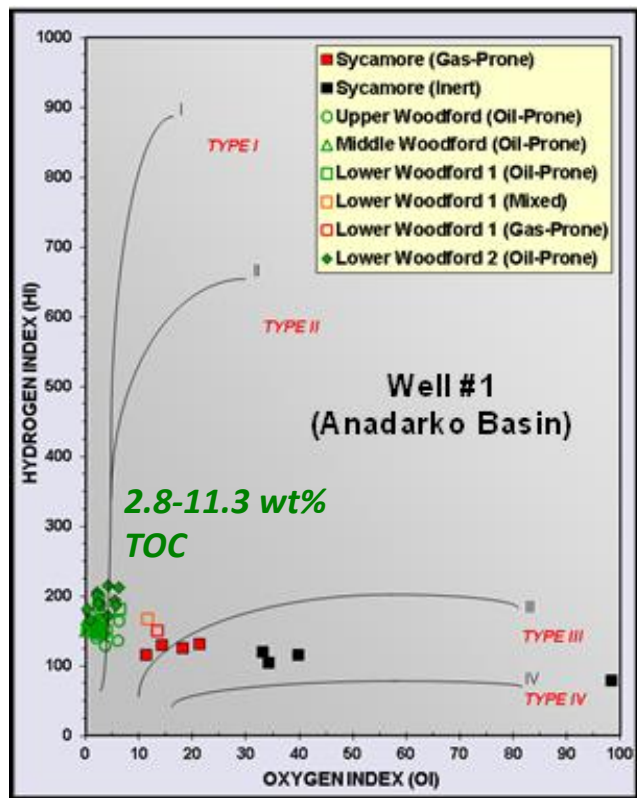
## SCOOP Area (Anadarko Basin)

Woodford GOR increases from east to west: **volatile oil** → **rich wet gas** → **leaner wet gas**.

Distribution and GOR/CGR of oil and wet gas controlled by thermal maturity of oil-prone Woodford source-rock beds?

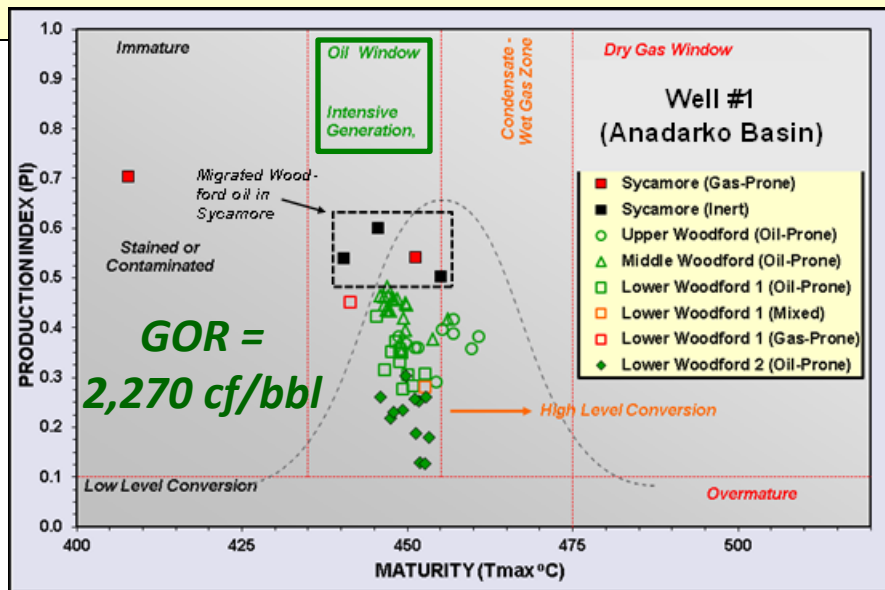


# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools



## Type and Thermal Maturity of Kerogen in Woodford Source Rocks (SCOOP Area)

Woodford Formation contains oil-prone kerogen in mid to late oil window at Well #1 (where volatile oil is produced).





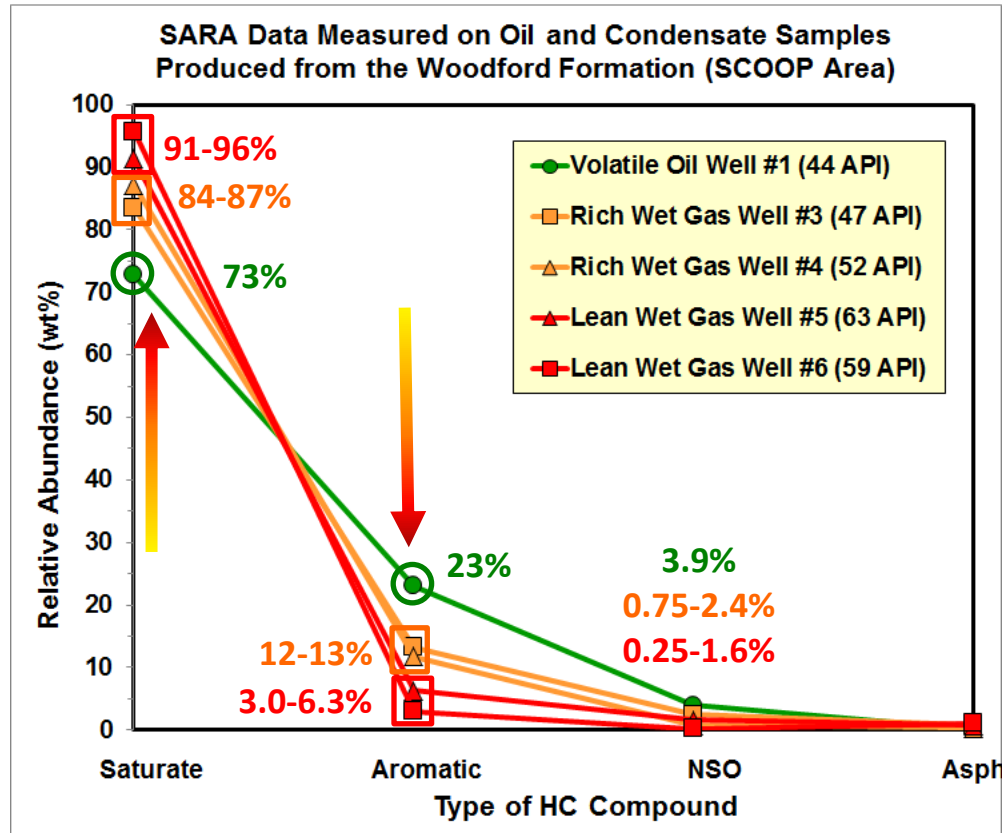
# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## SARA Data: Woodford Oil and Condensates (SCOOP Area)

Aromatic compounds crack to saturate compounds when oil cracks to wet gas at VR > 1.2% Ro.

$C_{15+}$  saturate compounds: Volatile oil < Rich wet gas < Leaner wet gas.

$C_{15+}$  aromatic compounds: Volatile oil > Rich wet gas > Leaner wet gas.



# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

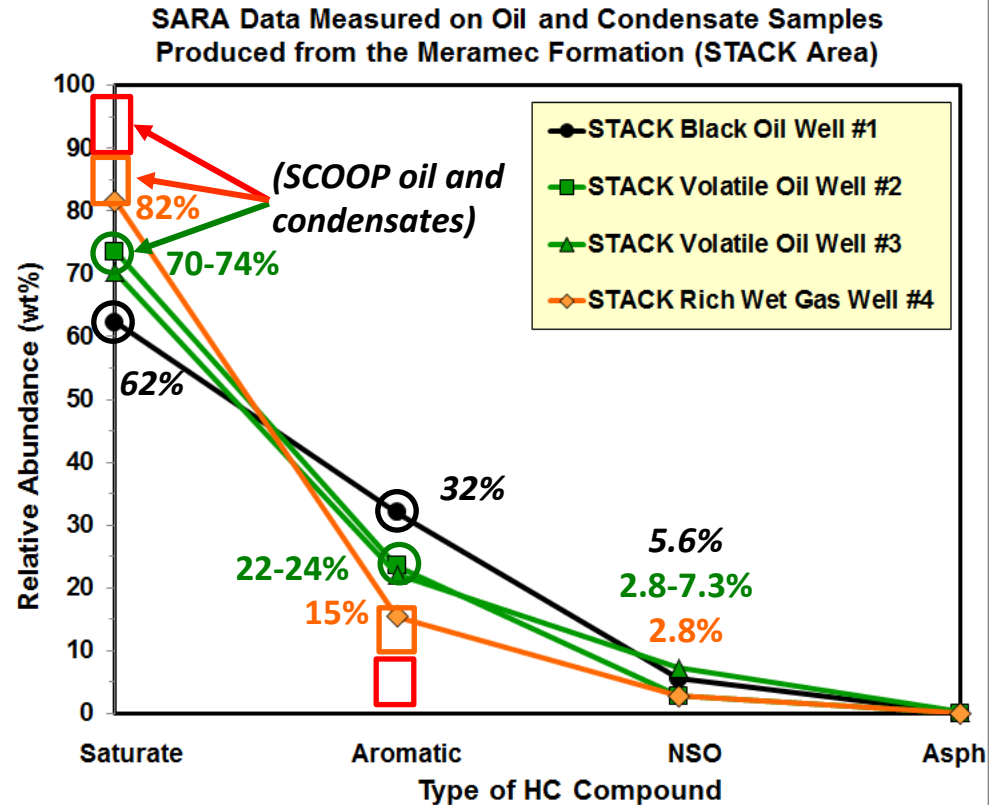
## SARA Data: Meramec Oil and Condensates (STACK Area)

C<sub>15+</sub> saturate compounds:

*Black oil* < *Volatile oil* <  
*Rich wet gas*.

C<sub>15+</sub> aromatic compounds:

*Black oil* > *Volatile oil* >  
*Rich wet gas*.



# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

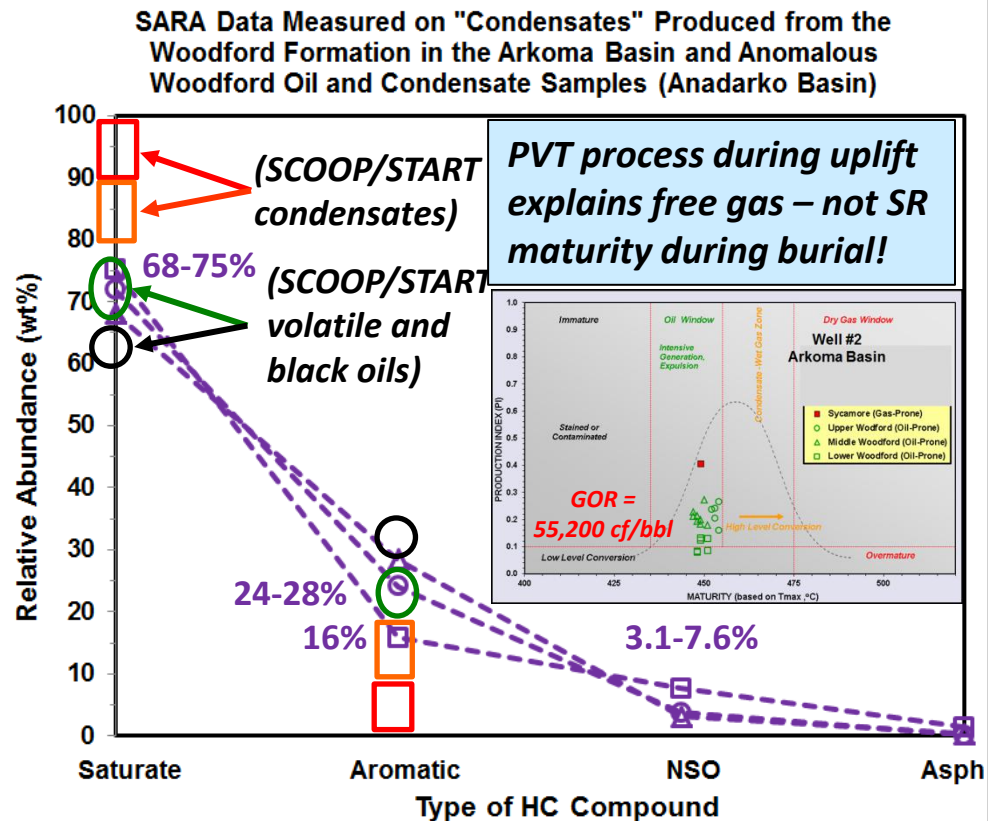
## SARA Data: Liquids from Woodford Gas Wells (Arkoma Basin)

GORs: 15,400 - 55,200 cf/bbl

Oil-prone Woodford SRs are in the oil window at Gas Well #2.

SARA data: 42-43°API liquids are **light oils** – not condensates.

Oil dropped below its bubble point during  $\approx 5,000'$  of basin uplift in Coal County, OK.

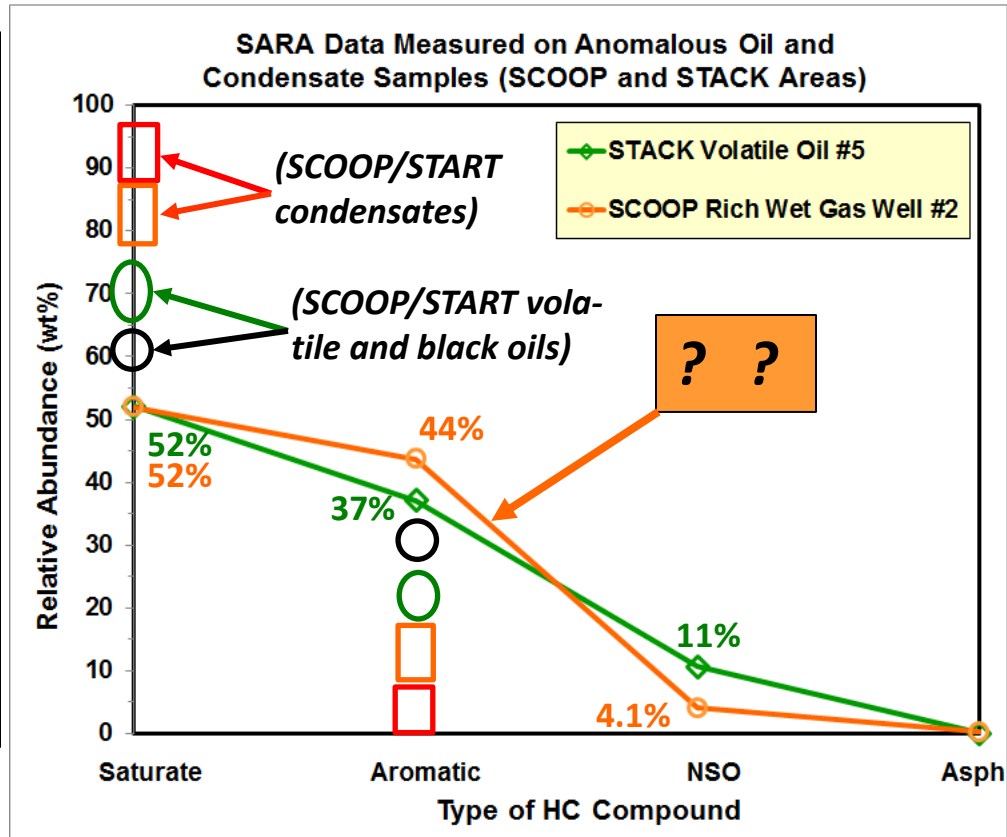


# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## SARA Data: Anomalous Volatile Oil & Condensate (SCOOP/STACK)

Low saturates and high aromatics in STACK volatile oil #5.

Relatively low gravity (40°API) of condensate from SCOOP rich wet-gas Well #2 (CGR = 150 bbl/MMcf) with similar low saturate and high aromatic compounds.

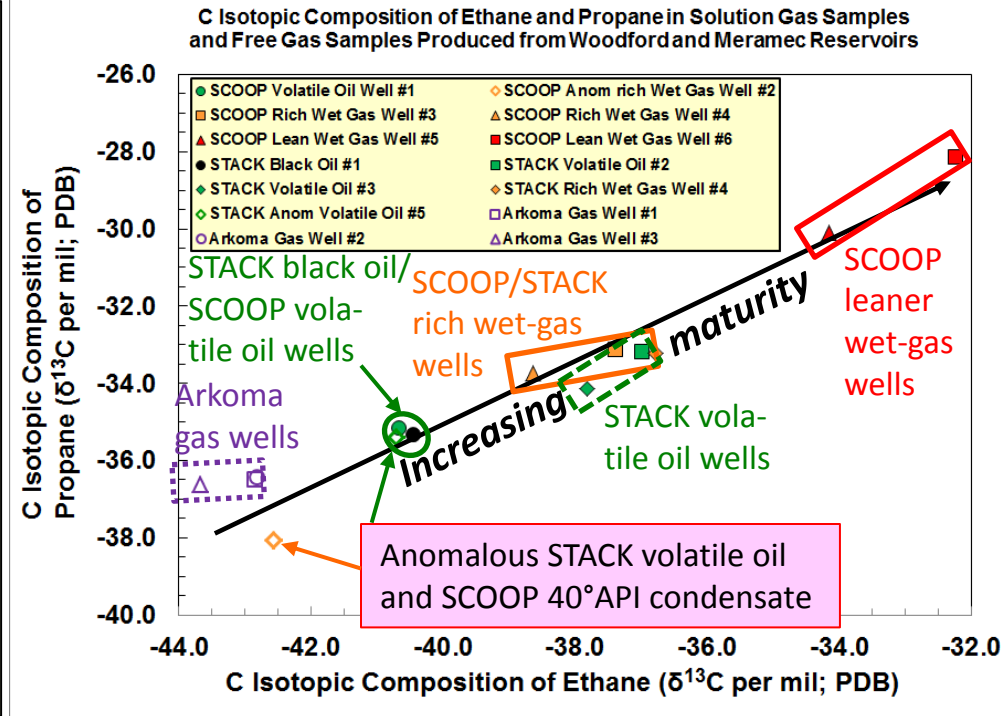


# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## C Isotopic Composition of Ethane and Propane in Gas Samples

C isotopic composition of HC gas compounds becomes heavier with increasing thermal maturity.

Relationship exists between GOR or CGR of reservoir fluids and the maturity of gas samples (except for the two anomalous fluids).





# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

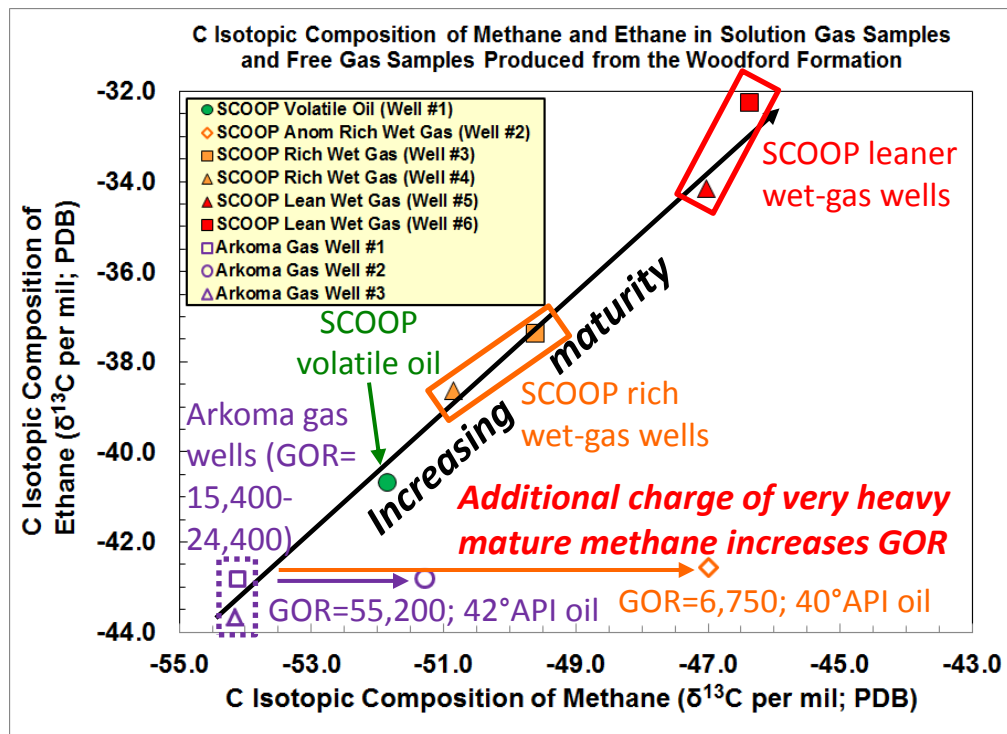
## C Isotopic Composition of Ethane and Methane in Gas Samples

C isotopic composition of methane also becomes heavier with increasing thermal maturity.

Relationship exists for most SCOOP samples between the GOR or CGR of reservoir fluids and the maturity of free or dissolved gas.

Heavier methane at Arkoma Gas Well #2 with 2-3X higher GOR, and in free gas at SCOOP well producing anomalous condensate.

Very dry, mature gas (>99% heavy methane) migrated into the Woodford reservoir at those locations, converting 40°API oil at SCOOP Well #2 into a wet-gas accumulation when the oil dissolved into the dry gas phase.



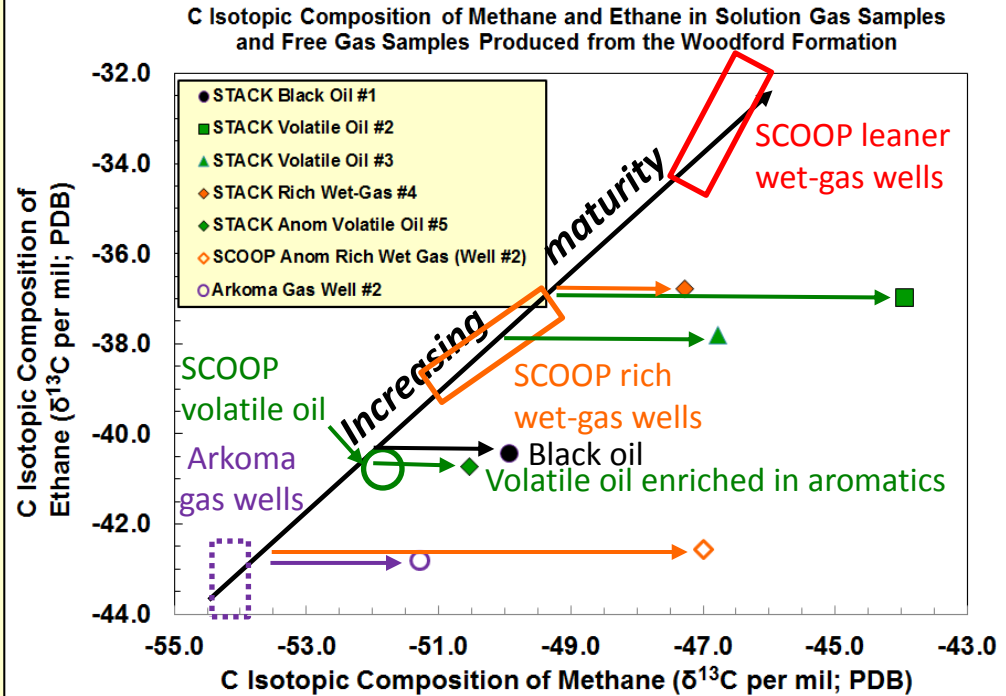
# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## C Isotopic Composition of Ethane and Methane (STACK Gas Samples)

Methane is isotopically-heavier than in most SCOOP gas samples.

Meramec reservoir received an additional charge of very mature dry gas.

The volatile oil sample enriched in aromatic compounds and depleted in saturate compounds was generated at relatively low (“black oil”) maturity.



# Evidence for Additional Dry Thermal Gas Charge in Woodford and Meramec Oil Pools

## Key Observation and Conclusions

C isotopic composition of HC gas compounds → kerogen maturity explains properties of most SCOOP oil and wet-gas pools.

Isotopically-heavy methane is present in gas produced from some wells completed in Woodford or Meramec reservoirs with GORs higher than expected (based on kerogen maturity).

At those well locations, very mature dry thermogenic gas has migrated into “permeable” Woodford and Meramec reservoirs.