Petroleum Systems of the San Joaquin Basin: Characterization of Oil and Gas Types

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References


Outline

- Introduction
- Oil characterization and correlation
- Oil-source rock correlation
- Map oil type distribution
- Gas characterization and correlation
- Gas origin
- Map gas type distribution
Oil Source Rocks

- Miocene Monterey Formation and equivalents
- Eocene Tumey formation
- Eocene Kreyenhagen Formation
- Cretaceous Moreno Formation
Previous Geochemical Studies


- **Kaplan and others 1988**, The petroleum geochemistry of crude oils and potential source rocks from the Paleogene of the San Joaquin and Ventura/Santa Barbara Basins, Pacific Section AAPG CD ROM Series 1, 2000

- **Peters and others, 1994**, Identification of petroleum systems adjacent to the San Andreas Fault, California, AAPG Memoir 60

Conclusions of Previous Studies

• Two main oil types in San Joaquin Basin
  – Miocene **Monterey** and equivalents
  – Eocene **Kreyenhagen**
• Other oil types recognized
  – Cretaceous Moreno
  – oil in Wygal Ss. Mbr. (Phacoides zone) of the Temblor Formation
Methods and Approach

- Analysis of 120 crude oils
  - Stable carbon isotopes
  - API gravity
  - Sulfur content
  - Biomarkers
- Integration with published data
- Define oil types
- Oil-source rock correlation
- Petroleum system mapping
Results - Isotopes

• Stable carbon isotopes show 3 oil types
  – EK
  – ET
  – MM

• All oil types derived from marine organic matter (below Sofer line)
Results – Pristane/Phytane

- Fourth oil type – CM recognized
- Some overlap between other 3 oil types
  - MM generally lower
  - EK generally higher
Results - Biomarkers

Saturated Hydrocarbons
GC-FID

3,4,5 ring Terpanes
m/z 191 GC-MS

Desmethyl Steranes
m/z 217 GC-MS
Results – Biomarker Ratios

• Bisnorhopane/hopane
  – MM oils have elevated values
  – CM, EK and ET oils have low values

• C26 tricyclics/C24 tetracyclic
  – MM oils have elevated values
  – EK and CM oils have low values

• C35/C34 extended hopanes
  – MM oils have elevated values
Mass Chromatograms of Terpanes - Monterey

Cal Canal field
Miocene Stevens reservoir

Elk Hills field
Pliocene Etchegoin reservoir

$m/z$ 191

*b* = bisnorhopane
$26 = C_{26}$ tricyclics
$24 = C_{24}$ tetracyclic
$O = \text{oleanane}$

hopane

$b = \text{bisnorhopane}$
$o = \text{oleanane}$
$g = \text{gammacerane}$
PCA Analysis

- Using isotopes and biomarkers
  - 4 oil types
  - 2 subtypes of EK
  - 3 subtypes of MM
PCA Analysis

Factor Scores

Factor Loadings
Results – Sulfur Content

• Not useful for correlation
• None of the oil types are derived from Type II-S kerogen (including the Miocene Monterey and equivalents)
Results - Gravity vs Sulfur

The diagram illustrates the relationship between API Gravity (degrees) and Sulfur (weight percent) for various kerogen types.

- **Kerogen Type II**: High Sulfur, Medium Sulfur, Low Sulfur

Legend:
- **MM**
- **MM outlier**
- **ET**
- **ET outlier**
- **EK**
- **EK outlier**
- **CM**
High Sulfur Oils in California

• Outside of San Joaquin Basin
  – High sulfur oils are derived from Monterey Formation in Santa Maria and offshore Ventura basins
  – Type II-S kerogen source

• In San Joaquin Basin
  – High sulfur oils due to biodegradation
Correlation to Previous Studies

• Isotopes and pristane/phytane
• Good correlation of most samples to 3 main oil types
Oil Correlation with Previous Studies

Polygons represent USGS oil types

Terrigenous organic matter

Marine organic matter

δ¹³C aromatic hydrocarbons (%) vs. δ¹³C saturated hydrocarbons (%)
Oil Correlation with Previous Studies

Polygons represent USGS oil types
Main Oil Types

- Monterey and equivalents
  - Middle and upper Miocene
- Kreyenhagen
  - Middle Eocene
- Tumey
  - Upper Eocene - Oligocene (?)

Cretaceous Moreno is a minor oil type
Published source rock data
- Kaplan and others (1988)
- Curiale and others (1985)
• Used only isotopes and pristane/phytane
Correlation

- MM correlates with Monterey Formation
- ET correlates with Eocene Tumey
- EK correlates with Eocene Kreyenhagen
Petroleum Systems Summary

- Cretaceous Moreno (.)
- Middle Eocene Kreyenhagen (!)
- Upper Eocene Tumey (.)
- Middle and Upper Miocene Monterey and equivalents (!)
Geographic Distribution of Oil Types

- Monterey
  - Southern basin
- Tumey
  - Central and West-Central basin
- Kreyenhagen
  - Western half of basin
- Moreno
  - Limited to one field (NW basin)
Geochemical Indicators Reflect Miocene Paleogeography

- Composition of MM oils reflect the increased contribution of terrigenous organic matter to the marine basin near the Miocene paleoshoreline.
- For example, oleanane content (angiosperms)
Gas Geochemistry -
Previous Geochemical Studies

- *Rudkin, 1968*
- *Jenden and others, 1988*
- *Jenden and Kaplan, 1989*
- *Kammerling and others, 1989*
- *Claypool and others, 2000*
Source Rocks

- Pliocene San Joaquin Formation
- Miocene Monterey Formation and equivalents
- Eocene Tumey formation
- Eocene Kreyenhagen Formation
- Cretaceous Moreno Formation
Conclusions of Previous Studies

- Northern basin gas may be a southern extension Winters-Domengine gas system in Sacramento Basin.
- Shallow gases in Pliocene reservoirs have biogenic source
- Associated gases related to oil source
Methods and Approach

• Analysis of 66 gas samples
  – Stable carbon isotopes (C₁ to C₅, CO₂)
  – Gas composition
• Integration with published data
• Define gas types
• Hypothetical source rocks/petroleum systems
75% of samples from oil fields (associated gas) Basin is an oil province.
Results – $\delta^{13}$C Methane vs Wetness

- 3 gas types
  - Thermogenic Dry (TD)
  - Thermogenic Wet (TW)
  - Biogenic (B)
- Mixed thermogenic and biogenic
  - TD-mixed
  - TW-mixed
Results – $\delta^{13}$C Methane vs Nitrogen

- Thermogenic Dry (TD) can be subdivided
  - TD-1 higher $\delta^{13}$C methane and nitrogen
  - TD-2 lower $\delta^{13}$C methane and nitrogen
- Biogenic (B)
  - Bo gas samples have high nitrogen
Results – $\delta^{13}C$ Methane vs $\delta^{13}C$ Ethane

- Thermogenic Wet (TW) can be subdivided
  - TW-1 higher $\delta^{13}C$ methane relative to ethane, distinct thermal maturity trend.
  - TW-2 lower $\delta^{13}C$ methane, weak thermal maturity trend.
  - TW-mixed has $\delta^{13}C$ methane < -45 per mil.
Thermogenic Dry (TD) Gas Type

- **TD-1**
  - Cretaceous reservoir rocks
  - Northern basin
  - Proposed Moreno source
    - Good source rock
    - Mature down-dip from fields

- **TD-mixed**
  - Cretaceous, Eocene, Miocene reservoirs
  - Northern basin
  - Moreno and biogenic mixed source

- **TD-2** – altered TW-2 gas type
Thermogenic Wet (TW) Gas Type

• TW-1
  – Eocene Oligocene reservoirs
  – Associated gas
  – Eocene Kreyenhagen or Tumey source

• TW-2
  – Mostly Miocene reservoirs
  – Associated gas
  – Miocene Monterey Formation source
  – Some altered to TD-2 gas type

• TW-mixed
  – Mixed biogenic and TW gas
Biogenic (B) Gas Type

- **B gas**
  - Pliocene San Joaquin Formation reservoir
  - Methanogenesis of San Joaquin Formation organic matter

- **Bo gas (two samples)**
  - Miocene reservoirs
  - High nitrogen
  - Unknown origin
Origin of Carbon Dioxide

- Samples with <2% CO2 and δ13C values less than zero per mil.
  - Thermal degradation of organic matter
- Samples with >2% CO2 and δ13C values greater than +2 per mil.
  - Residual gas from methanogenesis produced during petroleum biodegradation
Petroleum Systems

- TD-1 and TD-mixed
  - Moreno-Nortonville( . ) gas system
    - (Winters-Domengine Total Petroleum System)
- TW gas types (associated gas)
  - Included with corresponding Eocene or Miocene total petroleum systems
- B gas
  - Pliocene San Joaquin( . ) gas system
    - (Neogene Nonassociated Gas Total Petroleum System)