STRATUM
RESERVOIR

Production Allocation of Commingled Fluids Using Geochemistry

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Outline

- Production Allocation Introduction
- Why Geochemistry?
- Geochemistry Input Data
- Allocation Method Description
- Production Allocation Case Studies
- Few Concerns…
- Conclusion

Production Allocation:

Quantitative determination of the contribution of individual fluid sources to a commingled production stream

Production Allocation - Introduction

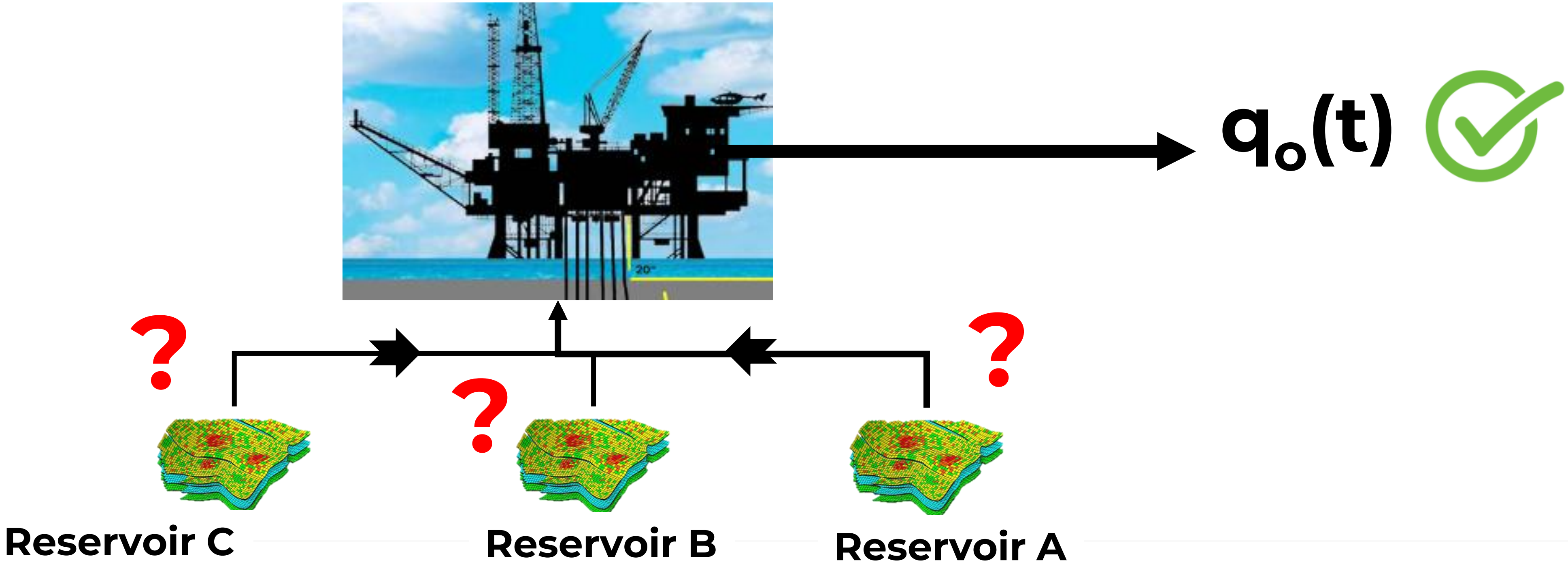
The importance of Production Allocation

- Reservoir compartment/sector contribution
- The share of Company A vs B
- Reservoir monitoring
- EOR – Sweep efficiency
- Failure detection (cementing, plugging)
- Production optimization (cleanout monitoring)
- Water resources – contaminated

Production Allocation

Introduction

- Fluid streams in production allocation can be referred to oil, gas and water
- Commingled fluid can be from pipeline, field, reservoirs or different reservoir sectors



$q_o(t)$ ✓

?

?

?

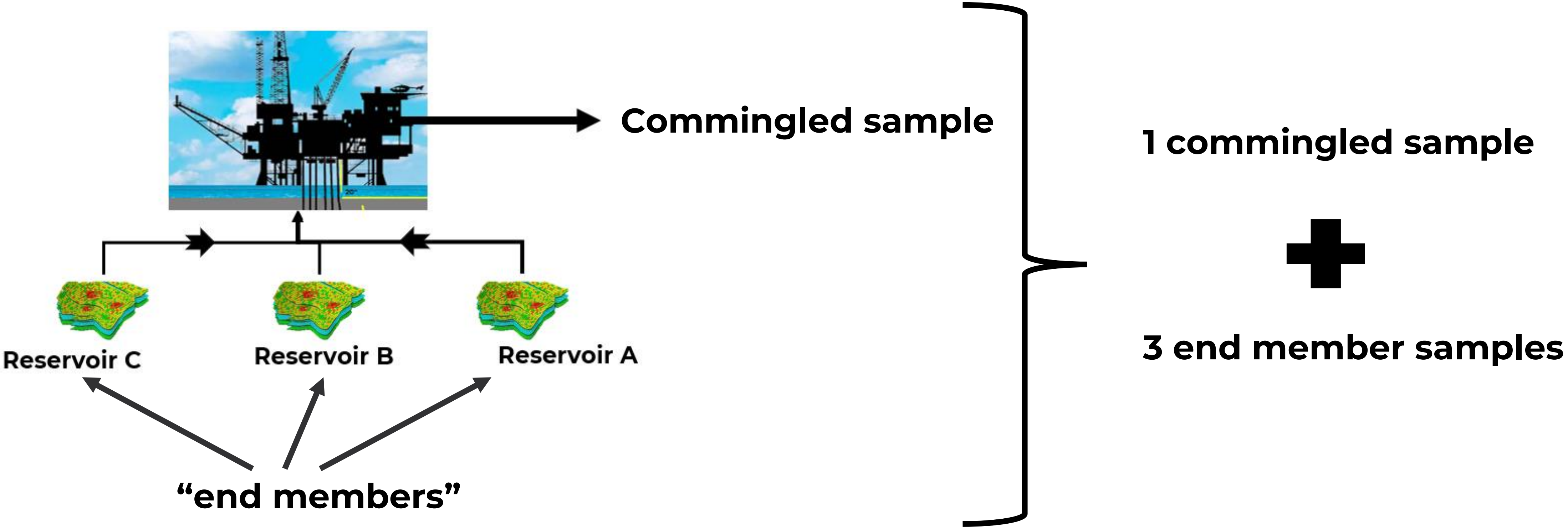
Reservoir C

Reservoir B

Reservoir A

Production Allocation

Introduction



Commingled sample

Reservoir C

Reservoir B

Reservoir A

“end members”

1 commingled sample

➕

3 end member samples

Our Aim:

To use **Geochemistry Data** to quantitative contribution of individual fluid sources to a commingled production stream

Why Geochemistry?

The importance

- ❑ Cost effective
    - Less than 1-2% of the of Production Logging tools (PLT)
    - Since it’s less expensive, can be run periodically
    - No need to shut in the well
    - Redundancy

- ❑ Wider application compared with PLT
    - Highly deviated wells
    - Unconsolidated formation
    - No installation or any type of wireline services required

Geochemistry Input Data

Main data: GC data

- Oil
  - GC-data whole oil
  - GC-MS (mass spectroscopy)
  - AKBs (alkylbenzenes in C8-C10)
- Gas
  - Light components (C_1,C_2,..)
  - Stable iso-tubes from C_1 and C_2: $\delta^{13}C$
  - Heavy component in gas sample may not mixed linearly
  - Special consideration in gas-water system regarding CO_2

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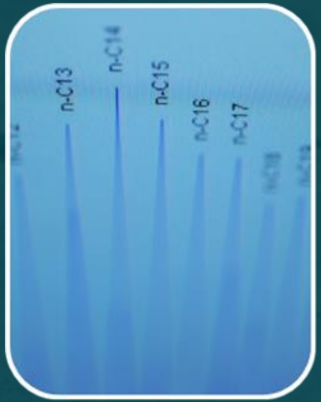
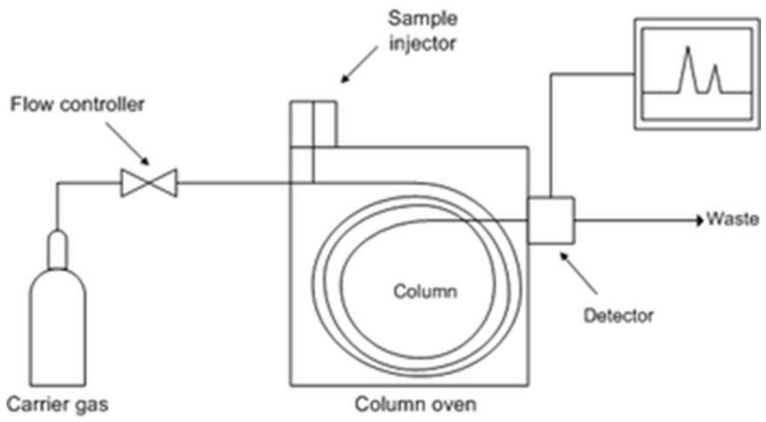


Geochemistry Input Data

Composition analysis of hydrocarbons and gases or liquids.

Methods are used for separation of various components and mixtures, and relative amounts are also determined.

Geochemistry Input Data



The carrier gas "picks up" the sample at the injection system, and applies it to the column in the GC oven.

column is 50 meters long

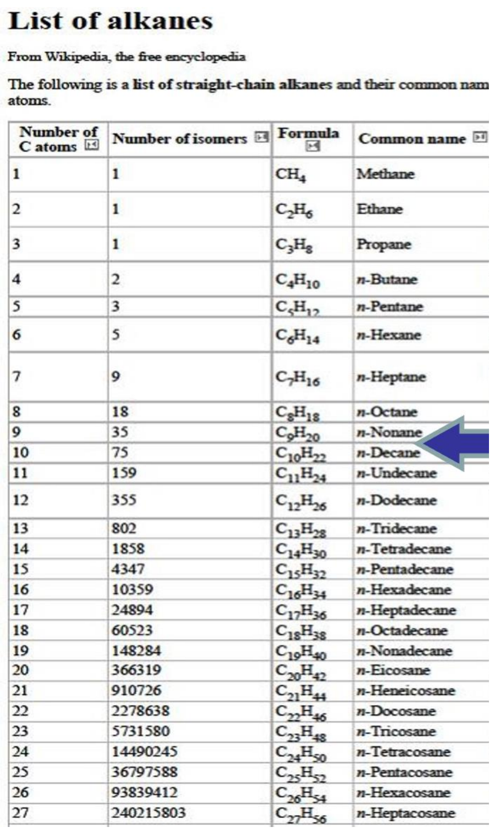
Sample is affected by the stationary phase on the inside of the column wall

At the same time, the travel speed of the components is affected by the temperature program in the oven, 30° to 300°C.
As a component reaches the detector, it has its own retention time.

Geochemistry Input Data

Komponentliste fra:

ASTM D5134-98
(ASTM D 1945-03)
Ca. 200 components



List of alkanes

From Wikipedia, the free encyclopedia

The following is a list of straight-chain alkanes and their common nam
atoms.

Number of C atoms	Number of isomers	Formula	Common name
1	1	CH_4	Methane
2	1	C_2H_6	Ethane
3	1	C_3H_8	Propane
4	2	C_4H_{10}	*n*-Butane
5	3	C_5H_{12}	*n*-Pentane
6	5	C_6H_{14}	*n*-Hexane
7	9	C_7H_{16}	*n*-Heptane
8	18	C_8H_{18}	*n*-Octane
9	35	C_9H_{20}	*n*-Nonane
10	75	$C_{10}H_{22}$	*n*-Decane
11	159	$C_{11}H_{24}$	*n*-Undecane
12	355	$C_{12}H_{26}$	*n*-Dodecane
13	802	$C_{13}H_{28}$	*n*-Tridecane
14	1858	$C_{14}H_{30}$	*n*-Tetradecane
15	4347	$C_{15}H_{32}$	*n*-Pentadecane
16	10359	$C_{16}H_{34}$	*n*-Hexadecane
17	24894	$C_{17}H_{36}$	*n*-Heptadecane
18	60523	$C_{18}H_{38}$	*n*-Octadecane
19	148284	$C_{19}H_{40}$	*n*-Nonadecane
20	366319	$C_{20}H_{42}$	*n*-Eicosane
21	910726	$C_{21}H_{44}$	*n*-Heneicosane
22	2278638	$C_{22}H_{46}$	*n*-Docosane
23	5731580	$C_{23}H_{48}$	*n*-Tricosane
24	14490245	$C_{24}H_{50}$	*n*-Tetracosane
25	36797588	$C_{25}H_{52}$	*n*-Pentacosane
26	93839412	$C_{26}H_{54}$	*n*-Hexacosane
27	240215803	$C_{27}H_{56}$	*n*-Heptacosane

Komponenter						
Methane	**n-Heptane**	2,2,5-Tm-Hexane	1,1,3-Tm-CyC6	N (10)	n-C12	n-C26
Ethane	Me-CyC6	t-1-Me-3-Et-CyC5	C9-N (6)	3-Me-Octane	C13 Group	C27 Group
Propane	c-1,2-Dm-CyC5	c-1-Me-3-Et-CyC5	2,5-Dm-Heptane	N (11)	n-C13	C28 Group
Isobutane	1,1,3-Tm-CyC5	t-1-Me-2-Et-CyC5	C9-P (1)	o-Xylene	C14 Group	n-C28
n-Butane	2,2-Dm-Hexane	2,2,4-Tm-Hexane	3,5-Dm-Heptane	1,1,2-Tm-CyC6	n-C14	C29 Group
Neopentane	Et-CyC5	1-Me-1-Et-CyC5	3,3-Dm-Heptane	N (12)	C15 Group	n-C29
Isopentane	2,5-Dm-Hexane	t-1,2-Dm-CyC6	N (1)	2,4,6-Tm-Heptane	n-C15	C30 Group
n-Pentane	2,2,3-Tm-Pentane	cc1,2,3-Tm-CyC5	C9-N (7)	N (13)	C16 Group	n-C30
2,2-Dm-Butane	2,4-Dm-Hexane	t-1,3-Dm-CyC6	C9-N (8)	P (2)	n-C16	C31 Group
CyC5					C17 Group	n-C31
2,3-Dm-Butane					n-C17	C32 Group
2-Me-Pentane					C18 Group	n-C32
3-Me-Pentane					Pristane C19H40	C33 Group
n-Hexane					n-C18	n-C33
2,2-Dm-Pentane					C19 Group	C34 Group
Me-CyC5					Phytane C20H42	n-C34
2,4-Dm-Pentane					n-C19	C35 Group
2,2,3-Tm-Butane					C20 Group	n-C35
Benzene					n-C20	
3,3-Dm-Pentane					C21 Group	
CyC6					n-C21	
2-Me-Hexane					C22 Group	
2,3-Dm-Pentane					n-C22	
1,1-Dm-CyC5	ct-1,2,4-Tm-CyC5	C9-N (4)	4-Et-Heptane	C10 Group	C23 Group	
3-Me-Hexane	c-1,3-Dm-CyC6	4,4-Dm-Heptane	N (7)	1,2,4-Tm-benzene	n-C23	
c-1,3-Dm-CyC5	3-Me-Heptane	Et-CyC6	4-Me-Octane	n-C10	C24 Group	
t-1,3-Dm-CyC5	ct-1,2,3-Tm-CyC5	Pr-CyC5	2-Me-Octane	C11 Group	n-C24	
3-Et-Pentane	3-Et-Hexane	2-Me-4-Et-Hexane	N (8)	1,2,3-Tm-benzene	C25 Group	
t-1,2-Dm-CyC5	t-1,4-Dm-CyC6	2,6-Dm-Heptane	N (9)	n-C11	n-C25	
2,2,4-Tm-Pentane	1,1-Dm-CyC6	C9-N (5)	3-Et-Heptane	C12 Group	C26 Group	

<u>For GC used in Geochemistry Analysis:</u>
<u>The type of program may change</u>

Example:

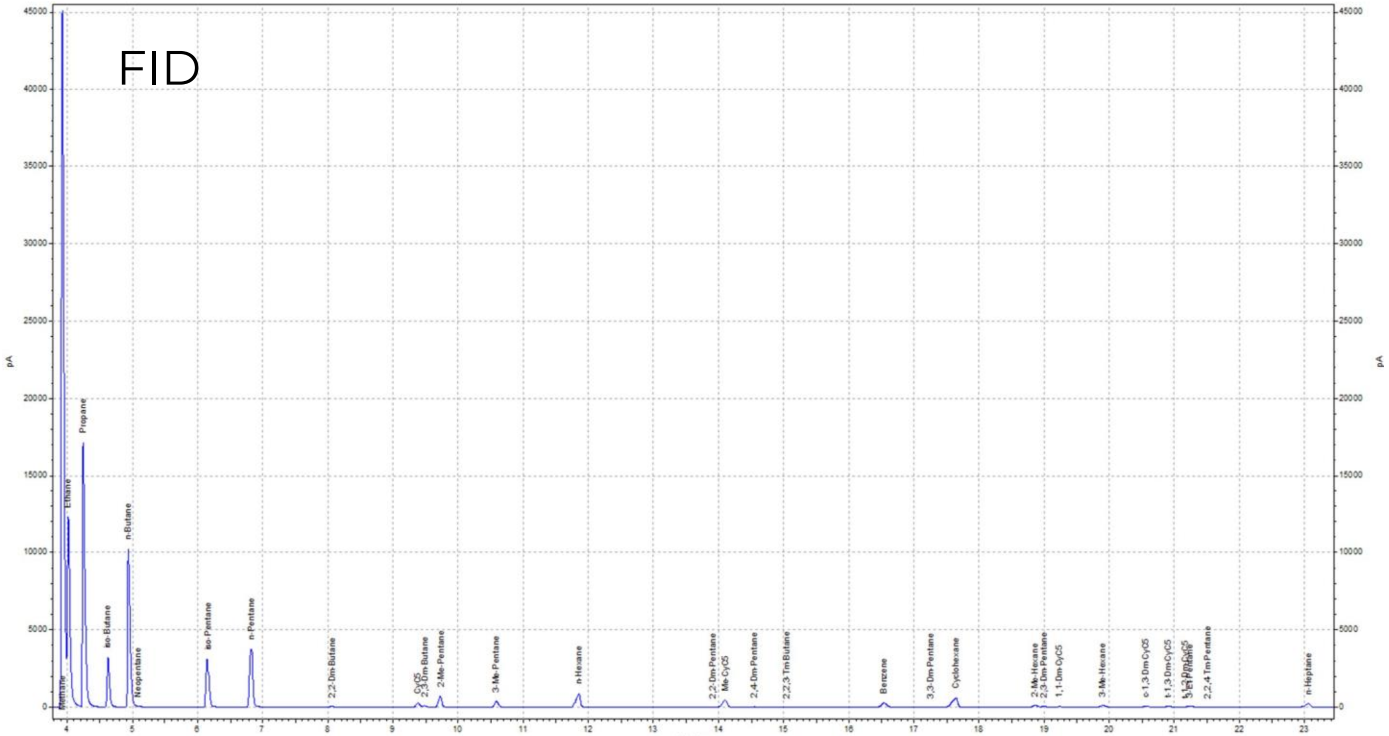
60 m column;
the injector T=275°C
Heating program: 35°C (hold 5 minutes),
3°/min. ramp to 320°C (hold for 20 minutes)

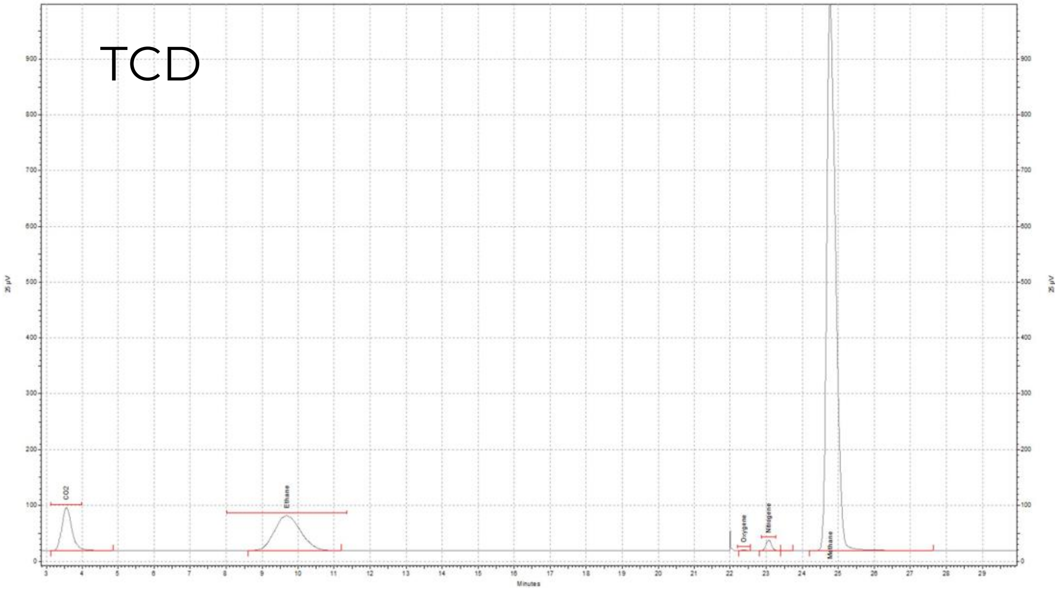
GC Gas

C1 – C12+ analysis

FID – Flame ionization detector

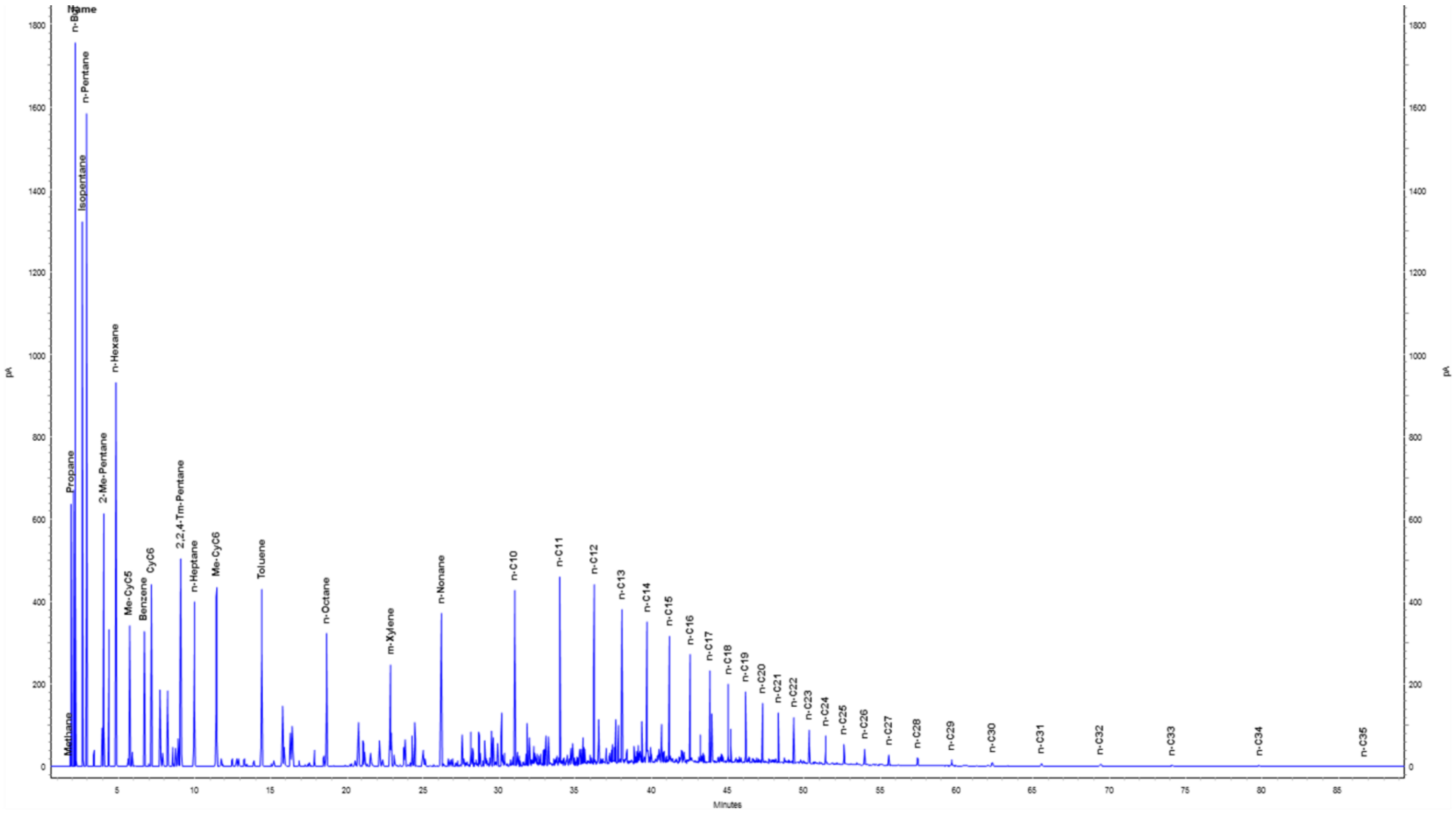
TCD – Thermal coductivity detector





GC Oil

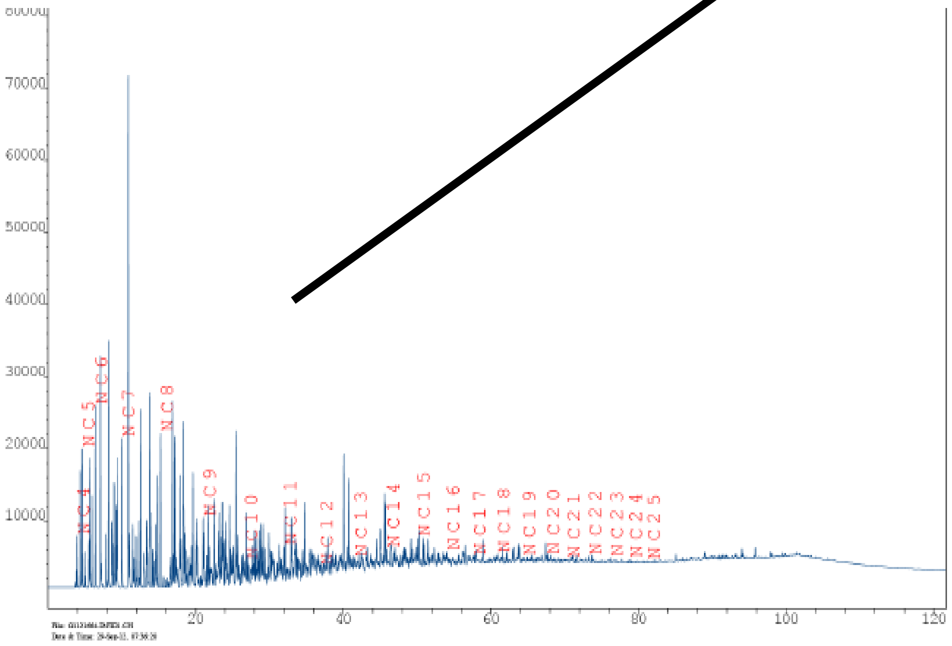
C1 – C36+ analysis



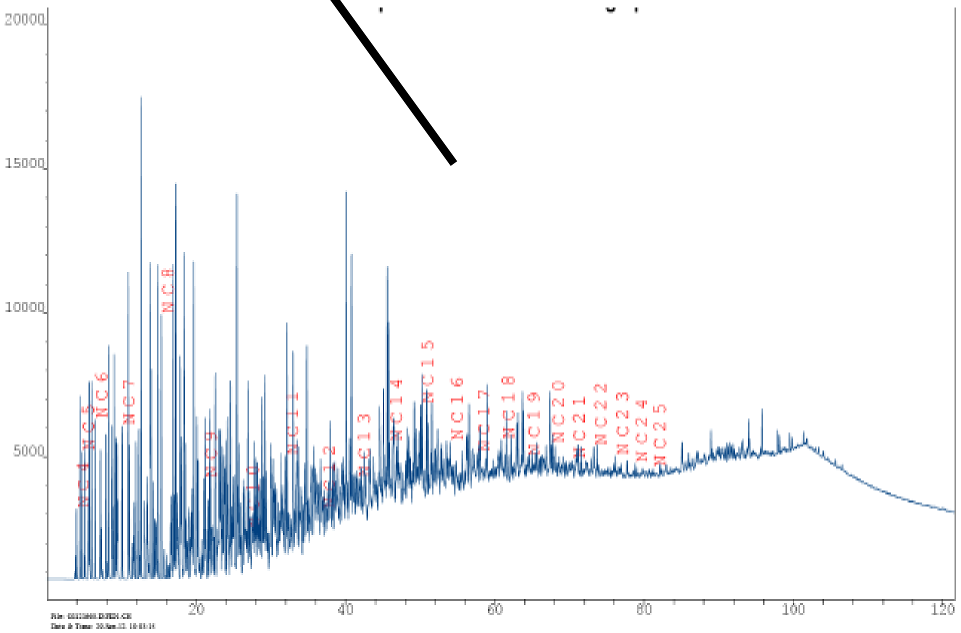
Geochemistry Data & Data Analysis

Main data is GC data

End members: Peak ratio or peaks of each Ci

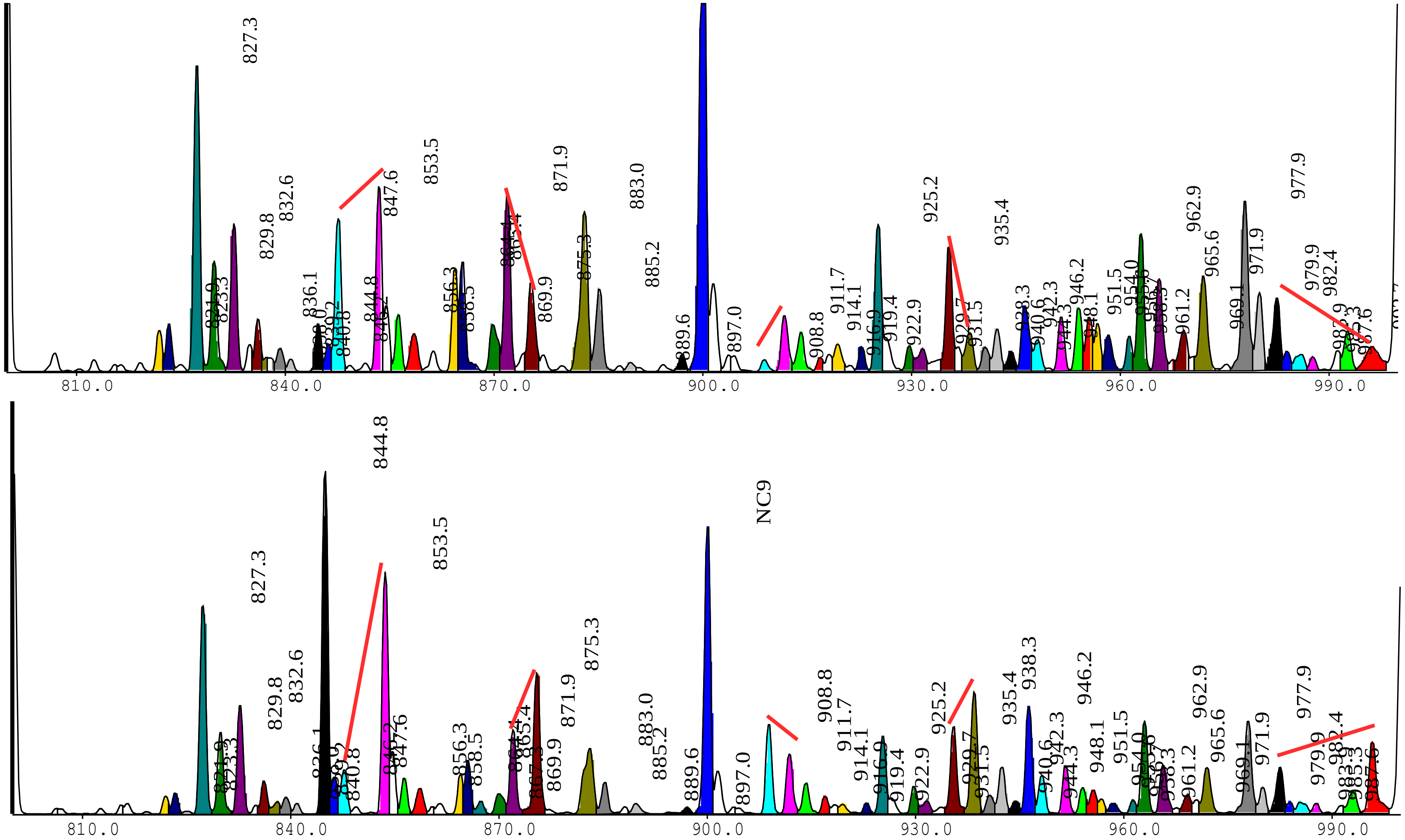


Sand A



Sand B

Geochemistry Data & Data Analysis

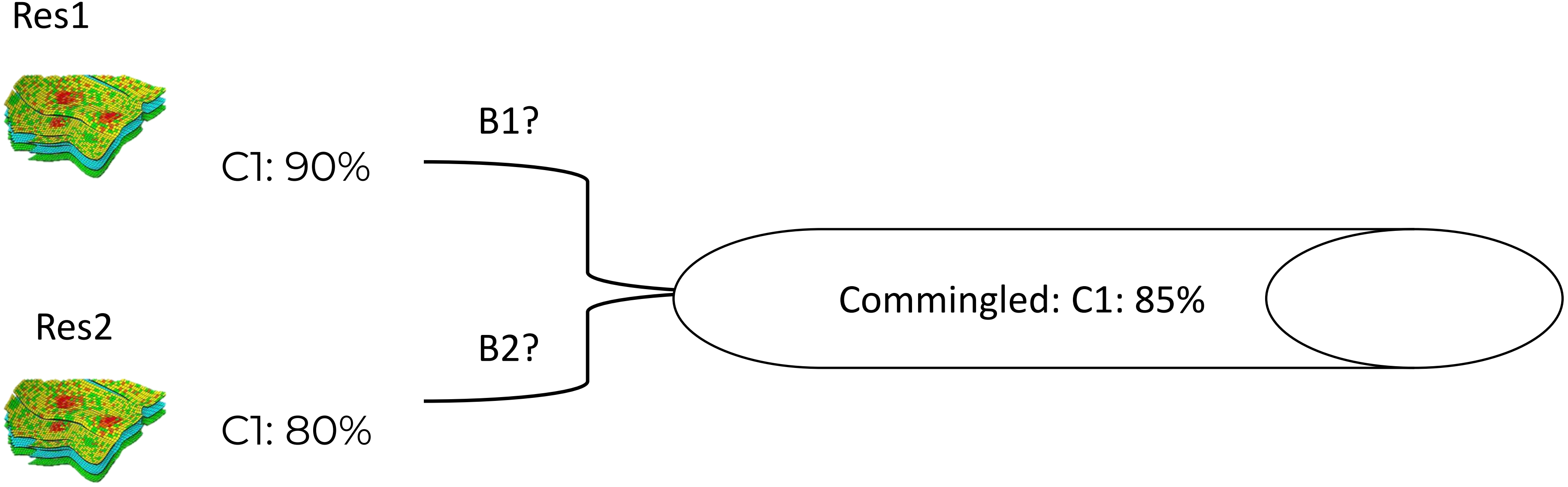


Source: Stratum Reservoir, Isotech, Mark A. McCaffrey

Allocation Method Description

Simple Example

How much of **reservoir 1** does contribute to the commingled flow streams?



Res1

C1: 90%

B1?

Res2

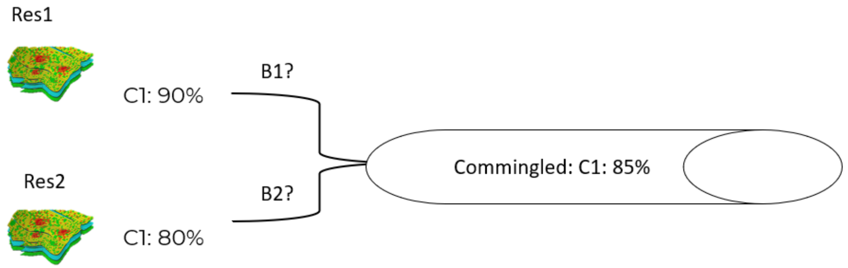
C1: 80%

B2?

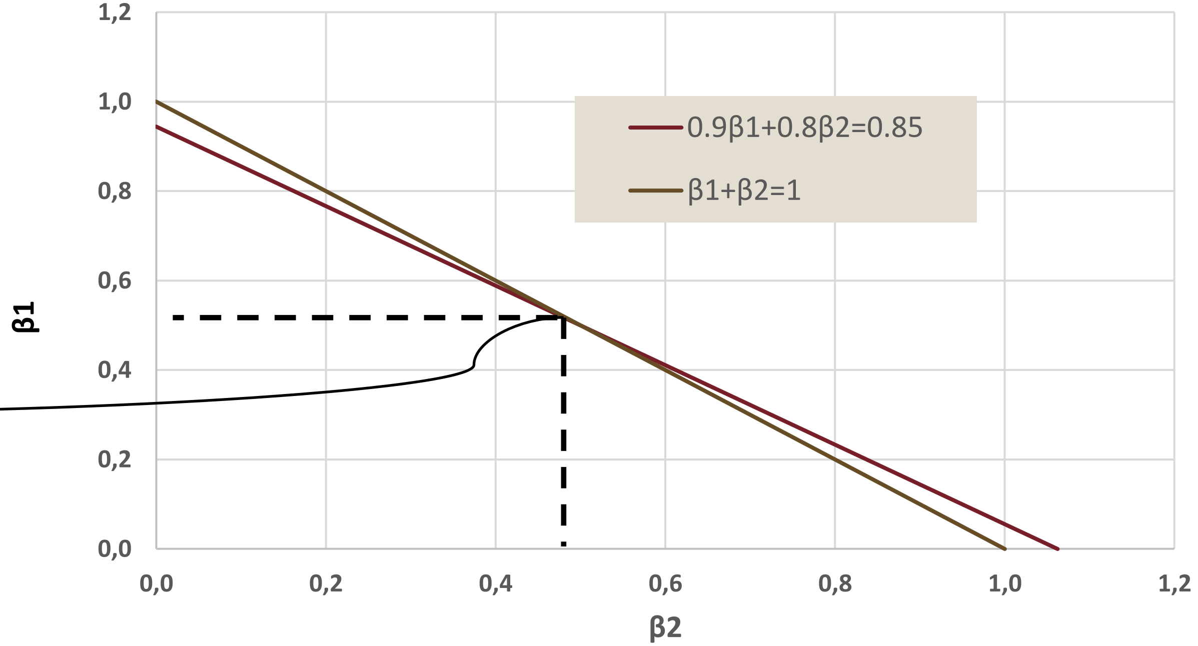
Commingled: C1: 85%

Allocation Method Description

Simple Example



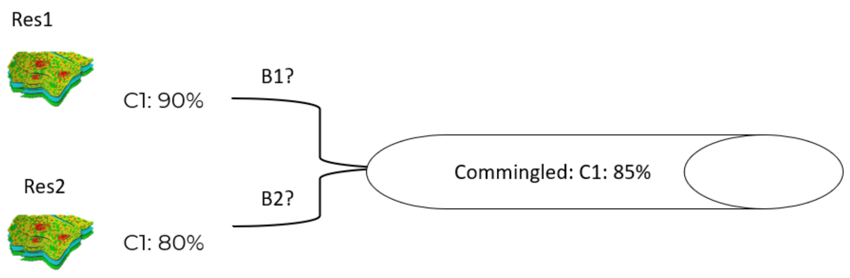
$$\begin{cases} 0.9 \times \beta_1 + 0.8 \times \beta_2 = 0.85 \\ \beta_1 + \beta_2 = 1 \end{cases}$$



$\beta_1 = 0.5$
$\beta_2 = 0.5$

Allocation Method Description

Real Case



Res1

C1: 90%

B1?

Res2

C1: 80%

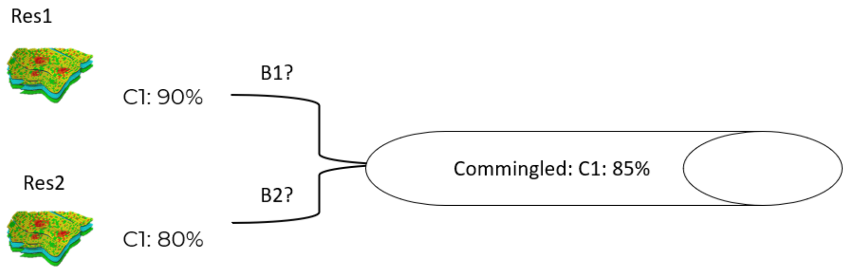
B2?

Commingled: C1: 85%

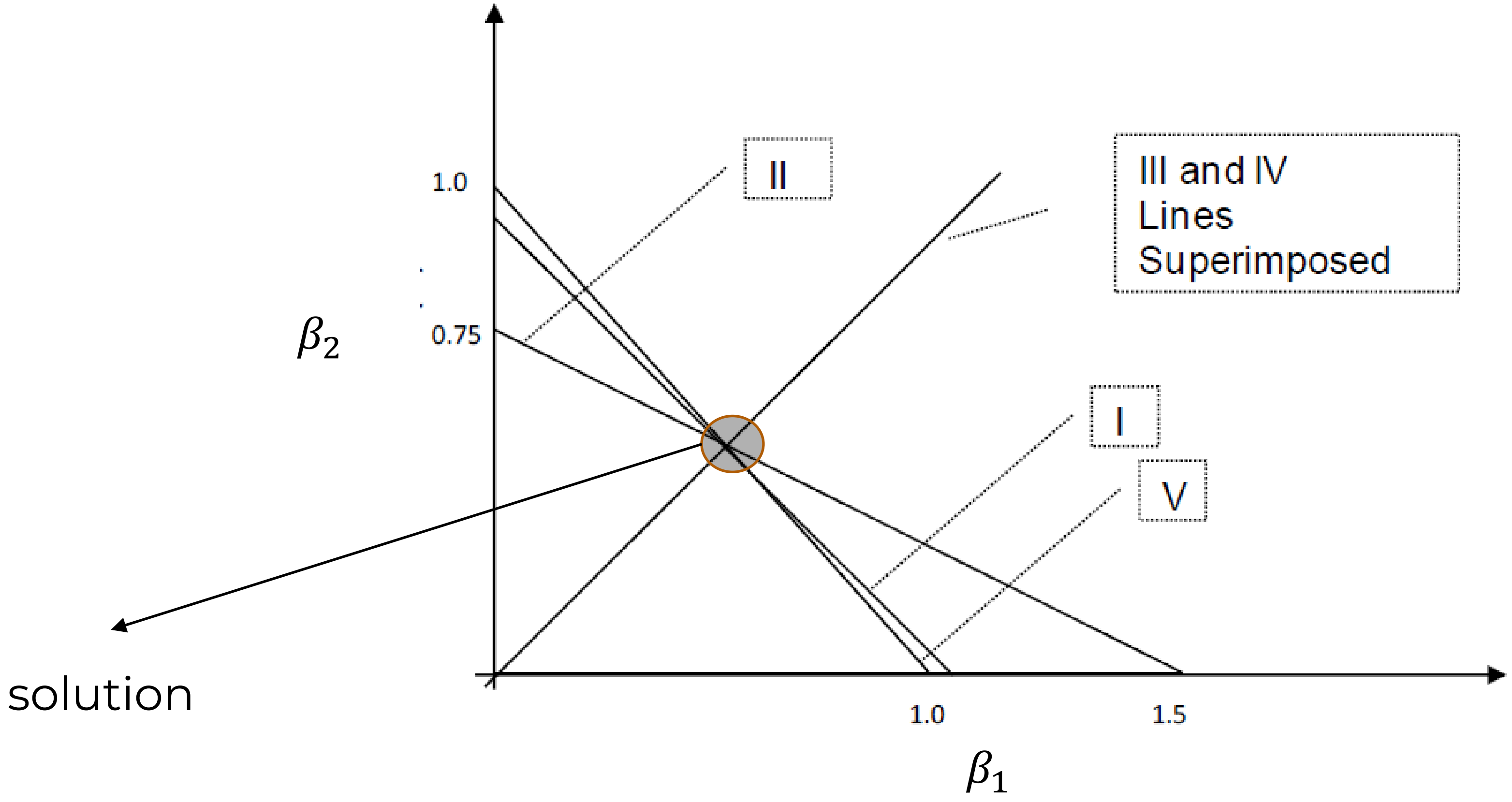
	C1	C2	$\delta^{13}C1$	$\delta^{13}C2$
End Member 1	90.00	10.00	-70.00	-50.00
End member 2	80.00	20.00	-60.00	-40.00
Commingled	85.00	15.00	-65.29	-43.33

Source: Adjusted from SPE144618: Stratum, Mark A. McCaffrey et al.

Allocation Method Description



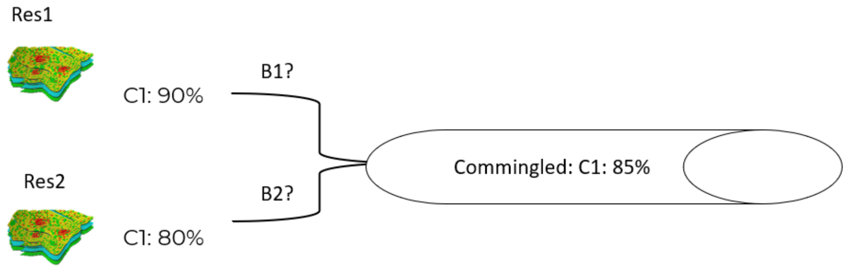
Real Case



Source: Adjusted from SPE144618: Stratum, Mark A. McCaffrey et al.

Allocation Method Description

Real Case



	C1	C2	$\delta^{13}C1$	$\delta^{13}C2$
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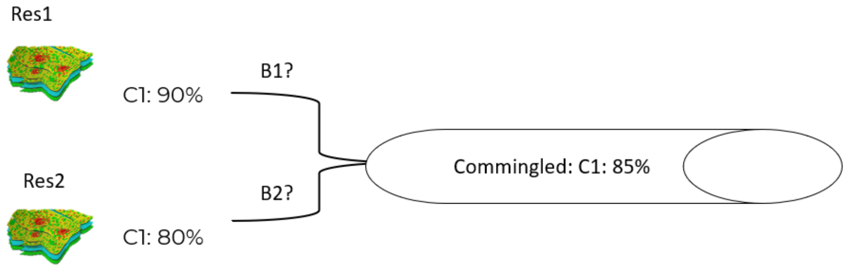
End member 2	80.00	20.00	-60.00	-40.00
Commingled	85.00	15.00	-66.00	-43.00

Assuming error in commingled – Isotope analysis

Source: Adjusted from SPE144618: Stratum, Mark A. McCaffrey et al.

Allocation Method Description



Res1

C1: 90%

B1?

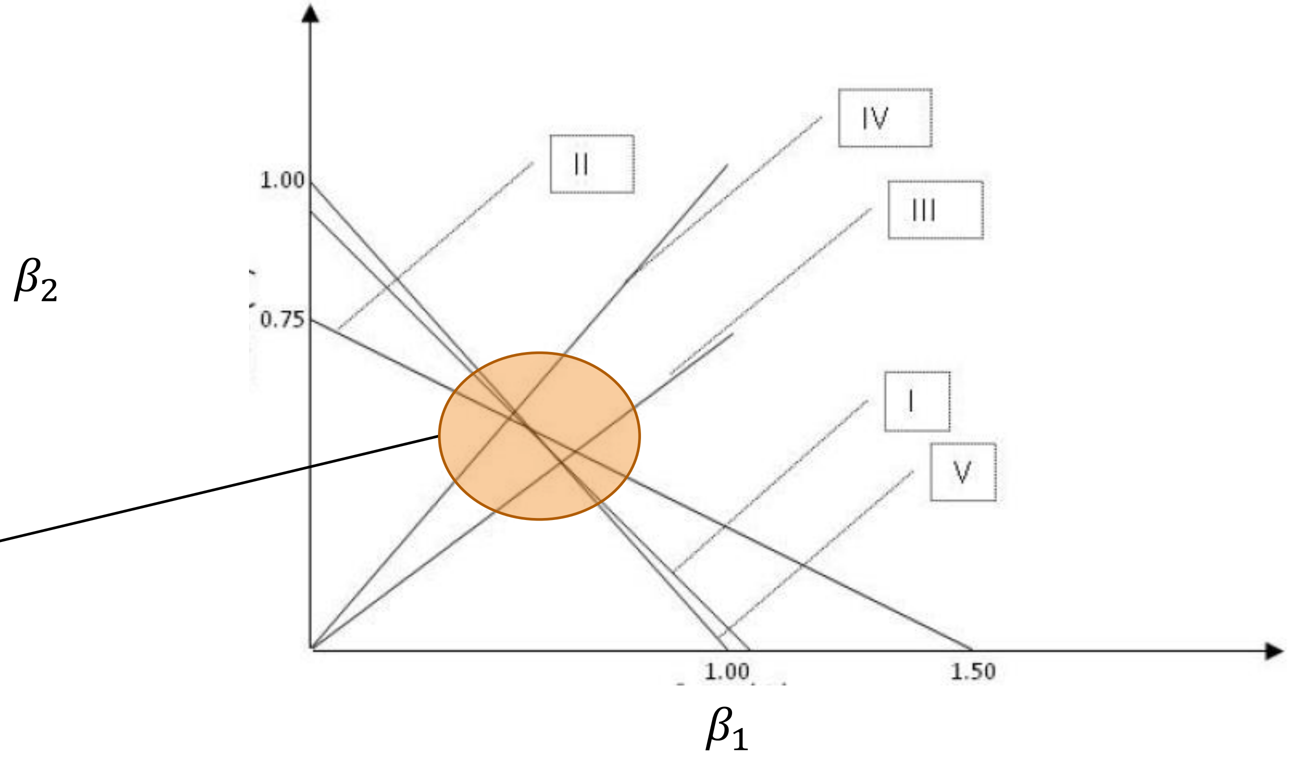
Res2

C1: 80%

B2?

Commingled: C1: 85%

Real Case



Solution is not valid?

Source: Adjusted from SPE144618: Stratum, Mark A. McCaffrey et al.

Allocation Method Description

McCaffrey et al. (2011)

$$\begin{tikzcd}
Y = \beta_1 X_1 + \beta_2 X_2 + \dots \beta_m X_m \arrow[r] \arrow[d] & \beta = (X'X)^{-1}X'Y \\
Y = \beta_1 X_1 + \beta_2 X_2 + \dots \beta_m X_{m\cdot} + eps &
\end{tikzcd}$$

Procedure:
Assume β → $\beta=(X'X)^{-1}X'Y$
Compute error in each sample point
Perform linear regression to minimize the error

↔

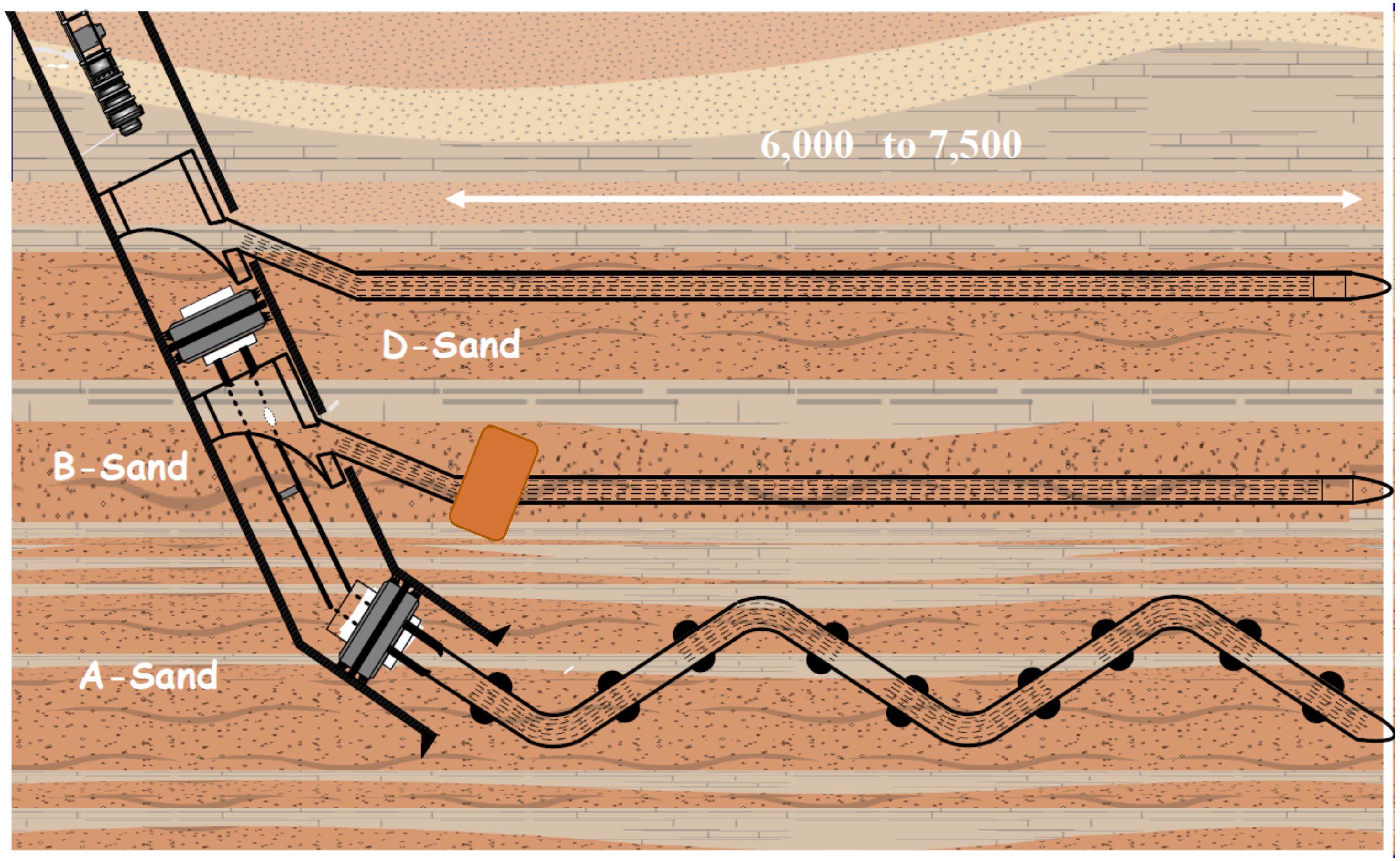
Scaling values for X & Y
Structural Variance within data set
Peak evaluation

Source: SPE144618: Stratum, Mark A. McCaffrey et al.

Production Allocation Case Studies using Geochemistry

West Sack Alaska -

- We monitor well for over 26 years of production
- Our analysis indicated which zone has sand barrier and required cleaning
- **Sand barrier in Sand B**



Source: Jensen et al. 2016, SPE1 108445-Ms

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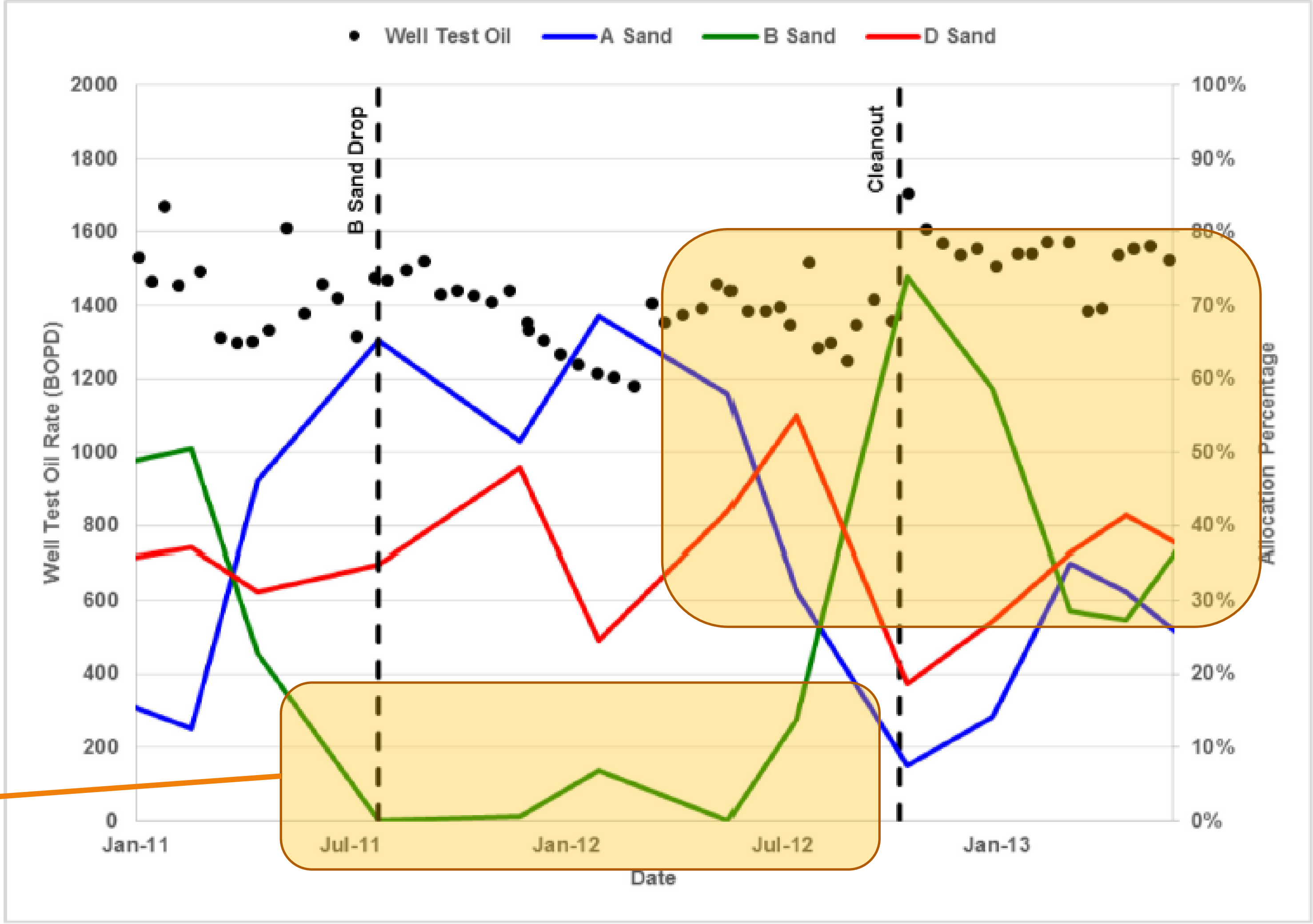


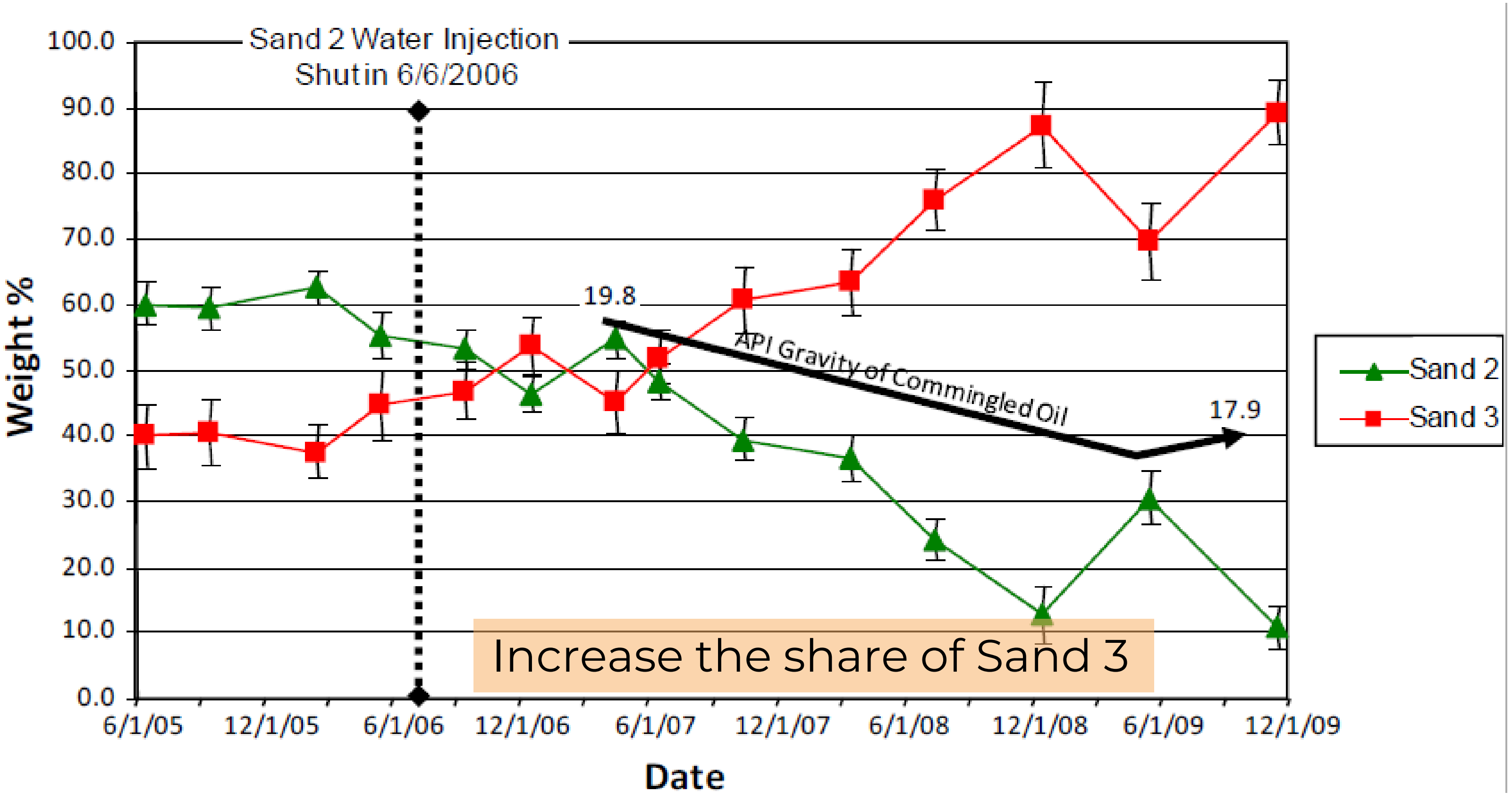
Tells you which sand requires cleanout

Source: Jensen et al. 2016, SPE1 108445-Ms

Case Study 2: shut in water injection

Case Study #2, Water Injection monitoring

- Commingling sand 2 (higher API) and Sand 3 (lower API)
- We have used more than 800 commingled samples
- Production from Sand 2 was initially supported by water injection but later shut-in

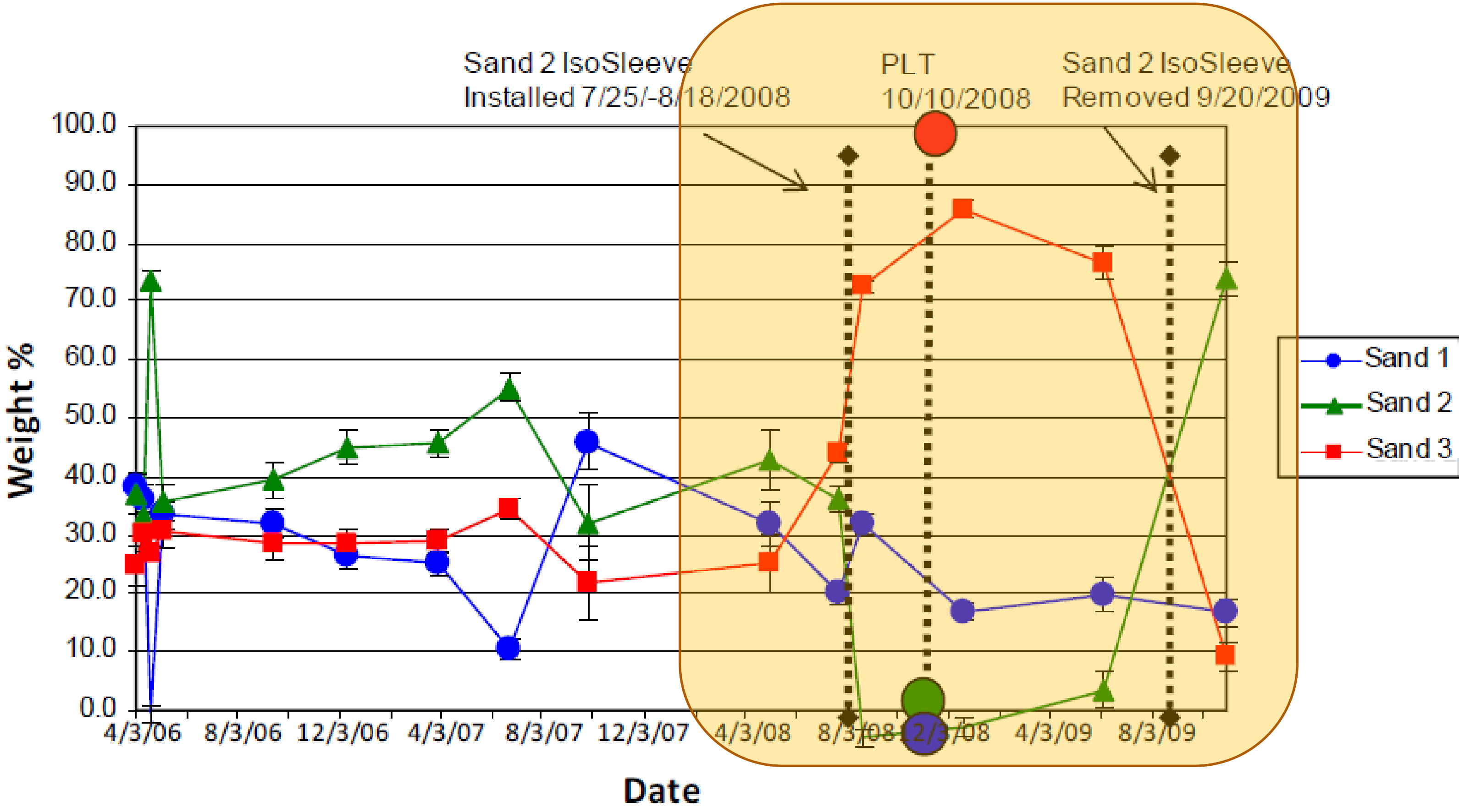


Source: SPE144618: Stratum, Mark A. McCaffrey et al.

Case Study 3: North Slope

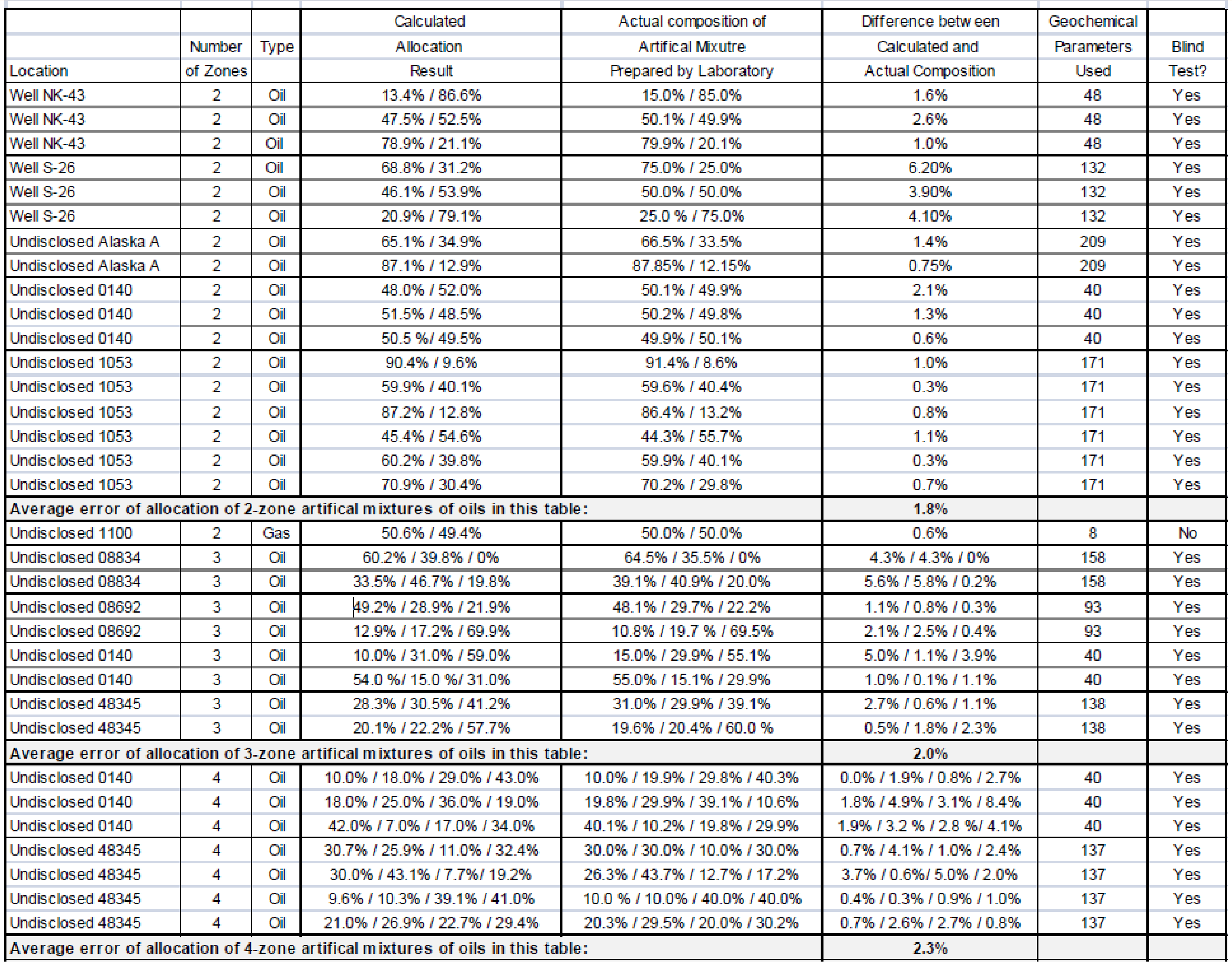
Case Study #3, Shut-off production monitoring

- Sand1+Sand2+Sand3
- Sand 2 was shut-in 28.07.2008 to 2008.08.11
- Geochemistry analysis showed fall in Sand 2 after IsoSleeve installed
- Geochemistry analysis showed increase in Sand 2 after IsoSleeve removed
- PLT failed to indicate the contribution of Sand 1 during shut-in period of Sand 2



Case Study 4: North Slope

Blind Test Measurement



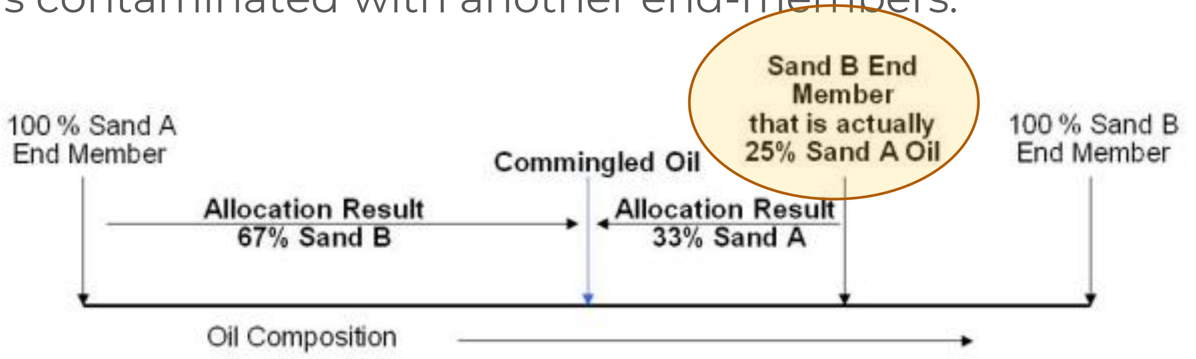
Location	Number of Zones	Type	Calculated Allocation Result	Actual composition of Artifical Mixutre Prepared by Laboratory	Difference betw een Calculated and Actual Composition	Geochemical Parameters Used	Blind Test?
Well NK-43	2	Oil	13.4% / 86.6%	15.0% / 85.0%	1.6%	48	Yes
Well NK-43	2	Oil	47.5% / 52.5%	50.1% / 49.9%	2.6%	48	Yes
Well NK-43	2	Oil	78.9% / 21.1%	79.9% / 20.1%	1.0%	48	Yes
Well S-26	2	Oil	68.8% / 31.2%	75.0% / 25.0%	6.20%	132	Yes
Well S-26	2	Oil	46.1% / 53.9%	50.0% / 50.0%	3.90%	132	Yes
Well S-26	2	Oil	20.9% / 79.1%	25.0 % / 75.0%	4.10%	132	Yes
Undisclosed Alaska A	2	Oil	65.1% / 34.9%	66.5% / 33.5%	1.4%	209	Yes
Undisclosed Alaska A	2	Oil	87.1% / 12.9%	87.85% / 12.15%	0.75%	209	Yes
Undisclosed 0140	2	Oil	48.0% / 52.0%	50.1% / 49.9%	2.1%	40	Yes
Undisclosed 0140	2	Oil	51.5% / 48.5%	50.2% / 49.8%	1.3%	40	Yes
Undisclosed 0140	2	Oil	50.5 %/ 49.5%	49.9% / 50.1%	0.6%	40	Yes
Undisclosed 1053	2	Oil	90.4% / 9.6%	91.4% / 8.6%	1.0%	171	Yes
Undisclosed 1053	2	Oil	59.9% / 40.1%	59.6% / 40.4%	0.3%	171	Yes
Undisclosed 1053	2	Oil	87.2% / 12.8%	86.4% / 13.2%	0.8%	171	Yes
Undisclosed 1053	2	Oil	45.4% / 54.6%	44.3% / 55.7%	1.1%	171	Yes
Undisclosed 1053	2	Oil	60.2% / 39.8%	59.9% / 40.1%	0.3%	171	Yes
Undisclosed 1053	2	Oil	70.9% / 30.4%	70.2% / 29.8%	0.7%	171	Yes
Average error of allocation of 2-zone artifical mixtures of oils in this table:					**1.8%**		
Undisclosed 1100	2	Gas	50.6% / 49.4%	50.0% / 50.0%	0.6%	8	No
Undisclosed 08834	3	Oil	60.2% / 39.8% / 0%	64.5% / 35.5% / 0%	4.3% / 4.3% / 0%	158	Yes
Undisclosed 08834	3	Oil	33.5% / 46.7% / 19.8%	39.1% / 40.9% / 20.0%	5.6% / 5.8% / 0.2%	158	Yes
Undisclosed 08692	3	Oil	49.2% / 28.9% / 21.9%	48.1% / 29.7% / 22.2%	1.1% / 0.8% / 0.3%	93	Yes
Undisclosed 08692	3	Oil	12.9% / 17.2% / 69.9%	10.8% / 19.7 % / 69.5%	2.1% / 2.5% / 0.4%	93	Yes
Undisclosed 0140	3	Oil	10.0% / 31.0% / 59.0%	15.0% / 29.9% / 55.1%	5.0% / 1.1% / 3.9%	40	Yes
Undisclosed 0140	3	Oil	54.0 %/ 15.0 %/ 31.0%	55.0% / 15.1% / 29.9%	1.0% / 0.1% / 1.1%	40	Yes
Undisclosed 48345	3	Oil	28.3% / 30.5% / 41.2%	31.0% / 29.9% / 39.1%	2.7% / 0.6% / 1.1%	138	Yes
Undisclosed 48345	3	Oil	20.1% / 22.2% / 57.7%	19.6% / 20.4% / 60.0 %	0.5% / 1.8% / 2.3%	138	Yes
Average error of allocation of 3-zone artifical mixtures of oils in this table:					**2.0%**		
Undisclosed 0140	4	Oil	10.0% / 18.0% / 29.0% / 43.0%	10.0% / 19.9% / 29.8% / 40.3%	0.0% / 1.9% / 0.8% / 2.7%	40	Yes
Undisclosed 0140	4	Oil	18.0% / 25.0% / 36.0% / 19.0%	19.8% / 29.9% / 39.1% / 10.6%	1.8% / 4.9% / 3.1% / 8.4%	40	Yes
Undisclosed 0140	4	Oil	42.0% / 7.0% / 17.0% / 34.0%	40.1% / 10.2% / 19.8% / 29.9%	1.9% / 3.2 % / 2.8 %/ 4.1%	40	Yes
Undisclosed 48345	4	Oil	30.7% / 25.9% / 11.0% / 32.4%	30.0% / 30.0% / 10.0% / 30.0%	0.7% / 4.1% / 1.0% / 2.4%	137	Yes
Undisclosed 48345	4	Oil	30.0% / 43.1% / 7.7%/ 19.2%	26.3% / 43.7% / 12.7% / 17.2%	3.7% / 0.6%/ 5.0% / 2.0%	137	Yes
Undisclosed 48345	4	Oil	9.6% / 10.3% / 39.1% / 41.0%	10.0 % / 10.0% / 40.0% / 40.0%	0.4% / 0.3% / 0.9% / 1.0%	137	Yes
Undisclosed 48345	4	Oil	21.0% / 26.9% / 22.7% / 29.4%	20.3% / 29.5% / 20.0% / 30.2%	0.7% / 2.6% / 2.7% / 0.8%	137	Yes
Average error of allocation of 4-zone artifical mixtures of oils in this table:					**2.3%**		

Source: SPE144618: Stratum, Mark A. McCaffrey et al.

Few Concerns…

Important

- If end members are similar in their profile, the resulted contribution factor could be erroneous
- It’s important to assure less contaminated end-members using BHS samples
- End members using cutting-extract may be contaminated with the extraction-solvent
- If one end members is contaminated with another end-members:



- It is not possible to solve the allocation problem if end-members are not possible
- It’s important to select the right-end members prior to analysis- PCA (principal component analysis)

Conclusion

in summary:

- All blind test proof measurement confirms the use of Geochemistry analysis for production allocation purpose.
- The Geochemistry production allocation is much less expensive compared with PLT, so it can be run frequently through the life of reservoir.
- The production allocation using geochemical analysis can be ran in highly deviated wells where PLT tools cannot be performed.
- The method of allocation with geochemistry can solve many issues in terms of failure detection, wellbore monitoring, EOR activities.
- All case studies shown in this presentation prove the successful implementation of geochemistry analysis in production allocation.
- The correct use of end-members is important can have a significant effect on the contribution fractions.

Thank You

Any Question?