Production Allocation and Monitoring Using Geochemical Methods

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Production Allocation and Monitoring

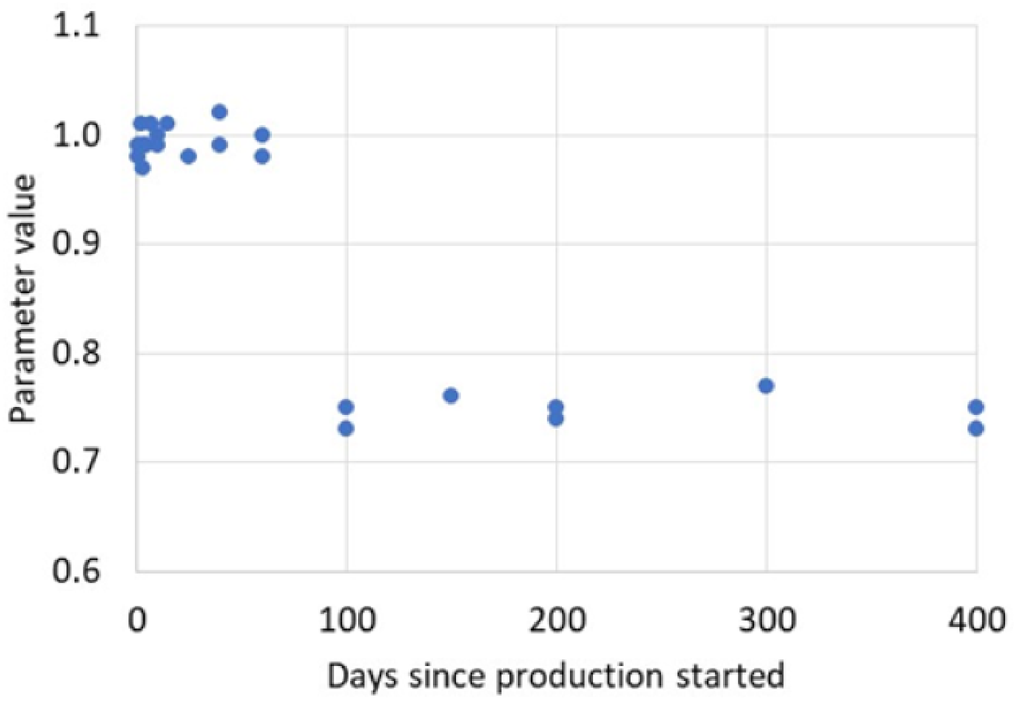
Outline

- Definitions of terms
- Why do it?
- Requirements for a successful study
- Analytical methods and reproducibility
- Data interpretation approaches
- Workflow summary
- Production allocation examples

Definition of Terms

Production Monitoring

- Analysis and interpretation of a time series of production fluids from the same source (e.g., a pipeline, field, reservoir, well, etc.).
- Goal of any monitoring program is to determine whether changes in the fluid chemistry are taking place and if so, explain why these changes have occurred, usually in relation to production-related processes.



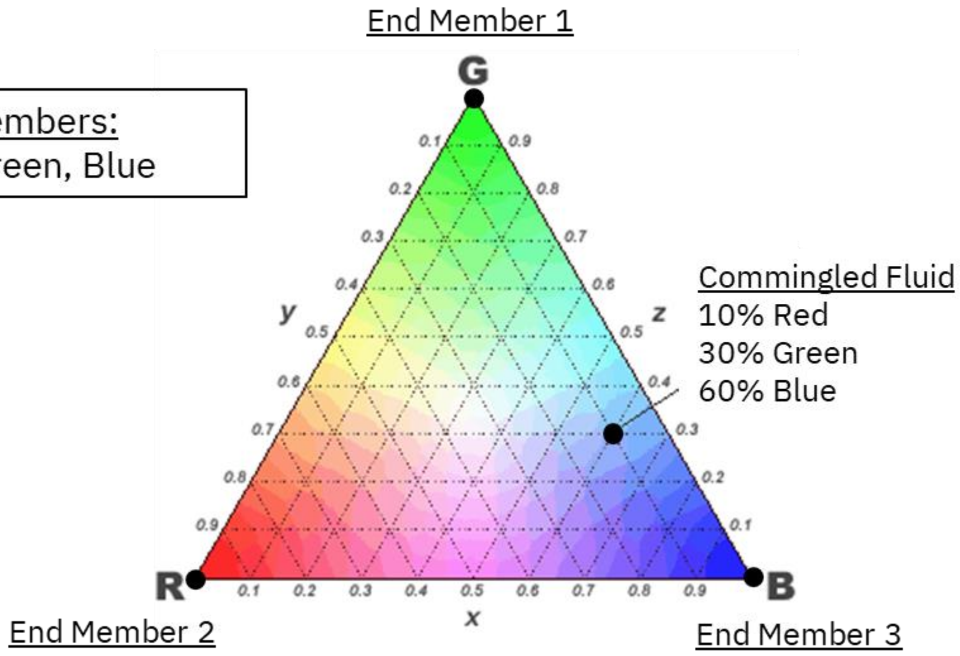
Definition of Terms

Production Allocation

- Quantitatively determine the portions of a commingled fluid which can be assigned to two or more individual fluid end member sources (e.g., a pipeline, field, reservoir, well).
- Assessment is done at a particular moment in time and is based upon the fluid chemistry.
- One of the easiest ways to conceptualise this is to imagine you are mixing a range of colored paints with the resulting mixture being determined by the contributions of the 'end member' colors used.

Maxwell Diagram of Colors

End members:
Red, Green, Blue



Commingled fluids:
The range of hues between the end members which can be quantified

Why do it?

Rationale behind Production Allocation

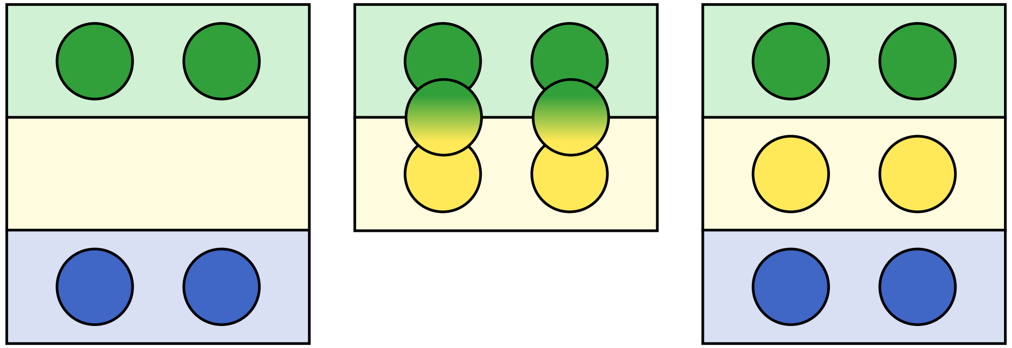
- If you understand where the petroleum comes from:
    - you can optimise production and increase ultimate recovery (geology/engineering).
    - owners of the assets can agree on revenue allocation (unitisation).
    - Government taxation can be properly allocated.
    - you can also recognise well interference or untapped resources. This way you can optimise well spacing.

Conventional Plays

- Multiple producing reservoirs in a field
- Multiple fields into a pipeline
- Multiple pipelines

Unconventional Plays

- As for conventional plays
- Well spacing to optimise production

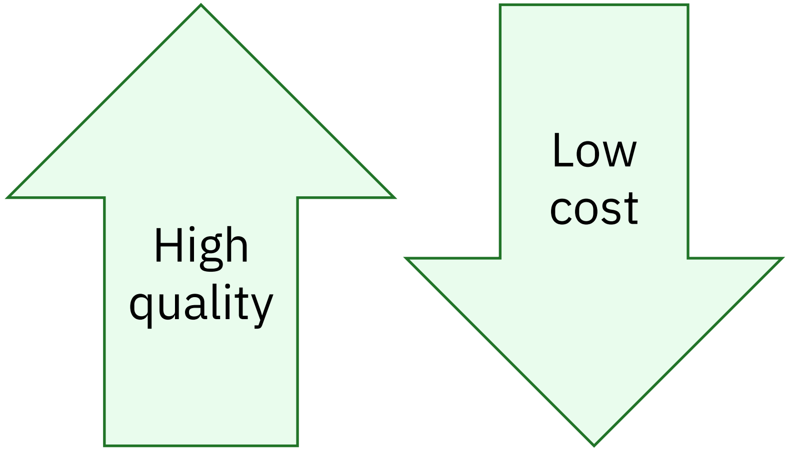


Optimal Well Spacing

Why do it?

Why use Geochemistry?

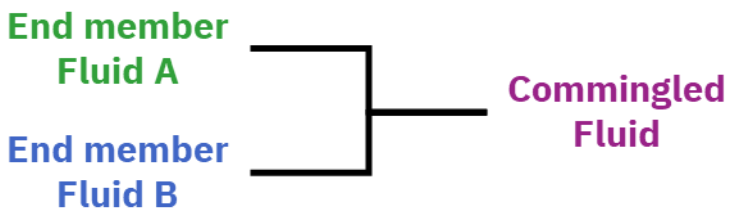
- Geochemically-based production methods require no intervention:
  - There is no risk to the well.
  - None of the risk entailed in additional operational activity.
- Analysis and interpretation is incredibly cheap:
  - Orders of magnitude less than that of a conventional PLT logging program.
  - There is no additional rig time, and no extra personnel required at the well site.
- Applicable to a wide range of fields irrespective of pressure, temperature, reservoir quality, reservoir fluid type etc.
- Uses directly measured data
  - It is not a surrogate such as a tracer or inferred from microseismic.

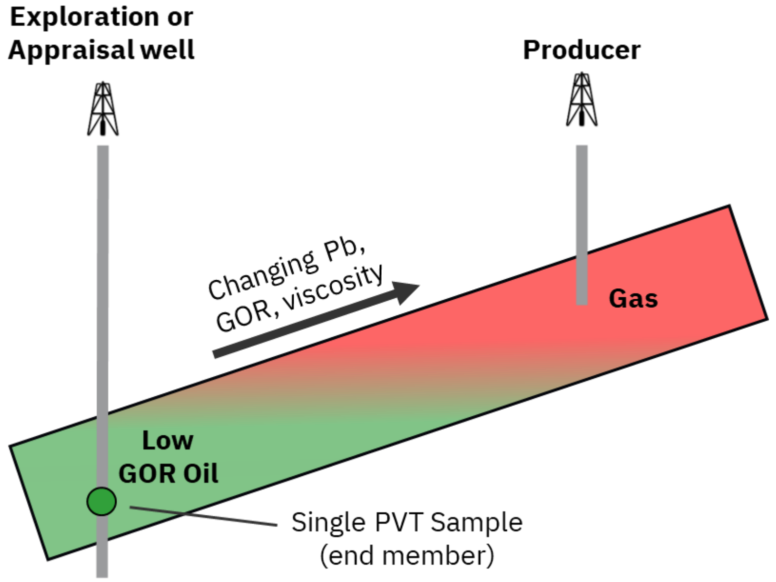


Requirements for a Successful Allocation Study

Sample Requirements

- Good quality samples.
  - Some limited drilling fluid contamination can be tolerated.
  - Can be an issue with rock samples and bottomhole samples.
- “End members” must exist (usually) for production allocation.
  - Not necessary for monitoring.
- End members are sufficiently different that they can be distinguished chemically.
  - The more end members there are, the more likely it is that two of them are similar.
- End members are representative.





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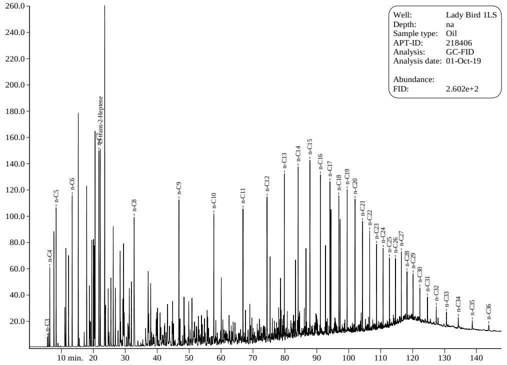
Analytical Methods and Reproducibility

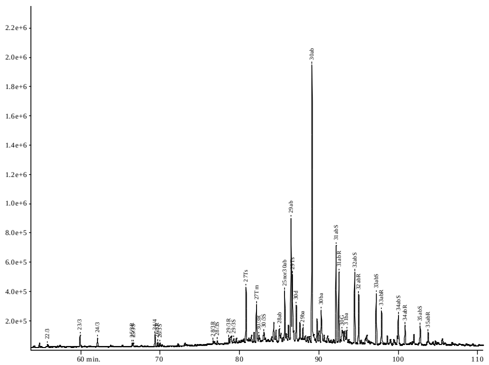
Analytical Methods

- Different analytical methods are selected depending on the nature of the fluid being examined:
  - Gases – Condensates – Light oils – “Normal” oils – Heavy oils
- Each project and the problems to be resolved will be unique, and analyses can be tailored to the individual job – **not a “one method” approach**.
- Possible analytical approaches include:
  - Whole oil gas chromatography (WO-GC). Can use gasolines or “grass peaks”.
  - GC-MS (saturates or aromatics), including alkylbenzenes (AKBs).
  - Gas composition and isotopes.

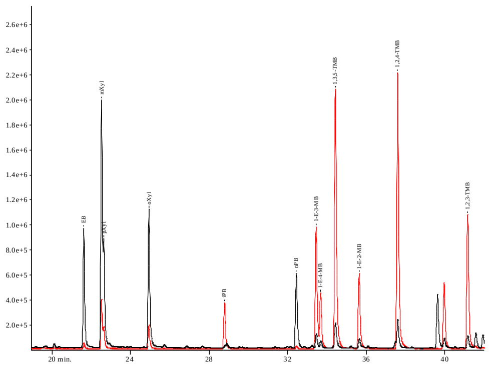
Whole Oil GC



GC-MS Saturates



GC-MS Alkylbenzenes



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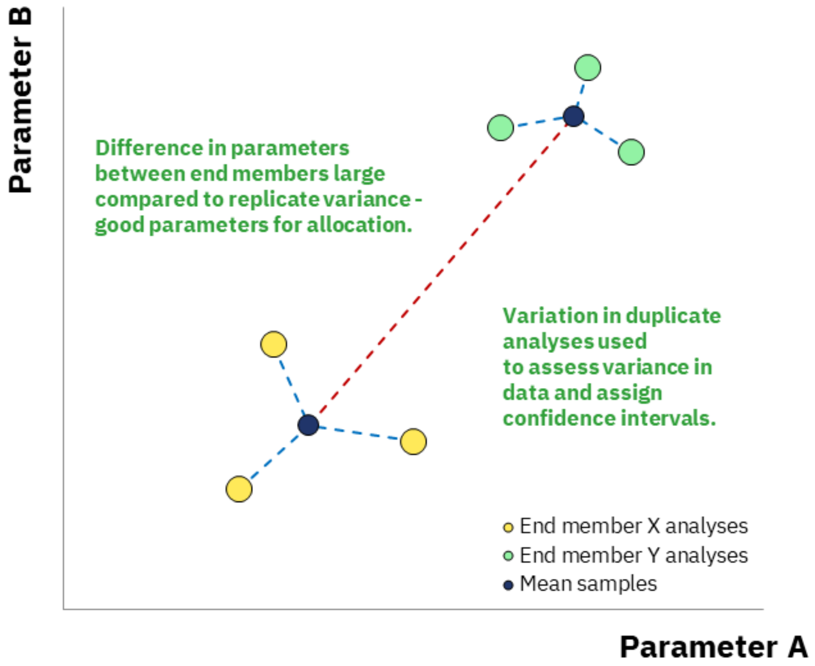
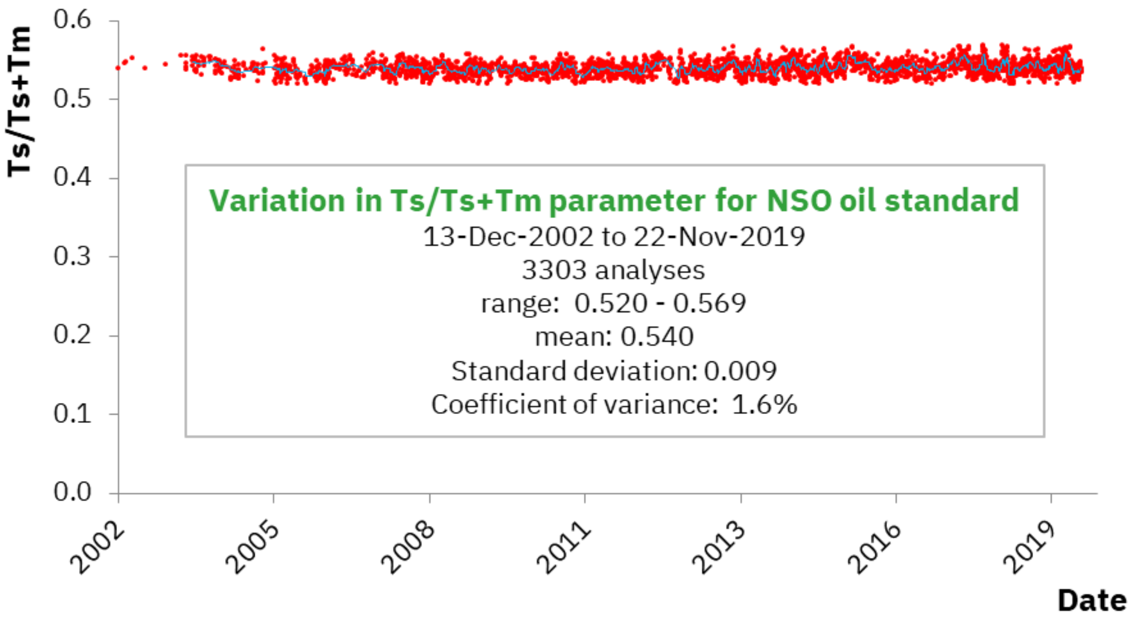
Analytical Methods and Reproducibility

Analytical Reproducibility over Time

- A key factor in reducing uncertainty but also reducing the number of replicate analyses required (and hence cost) is the reproducibility over time of analyses
- APT has a strong track record in high quality, highly reliable analyses where samples analysed years apart generate reproducible data.





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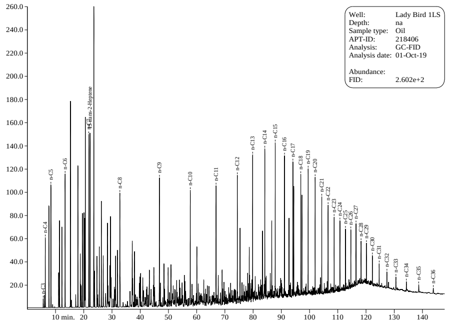
Data Interpretation Approaches

Data Manipulation – End-members – Replicate Analyses

- For all analytical methods (e.g., GC-WO, GC-MS) there are two main approaches to comparing end-members and calculating mixtures:
  - Peak concentrations (or areas/heights as proxy concentrations).
  - Peak ratios.
- Peak ratios (without accompanying peak concentration data) requires calibration (known laboratory prepared mixtures of the end-members; number should be ≥ number of end-members).
- Regardless of the details of the data processing method used the most important factor is the **reliability and reproducibility of the analytical data**.
- End-members must be analysed and they must all be geochemically distinct in some way; geochemical differences between end-members must be statistically significant and consistently reproducible by the laboratory analytical method(s) employed.
- The number of end-members is usually limited (by definition ≥ 2, typically 2-4; limitation is imposed by the need for all of the end-members to be distinctive, not the deconvolution algorithm).

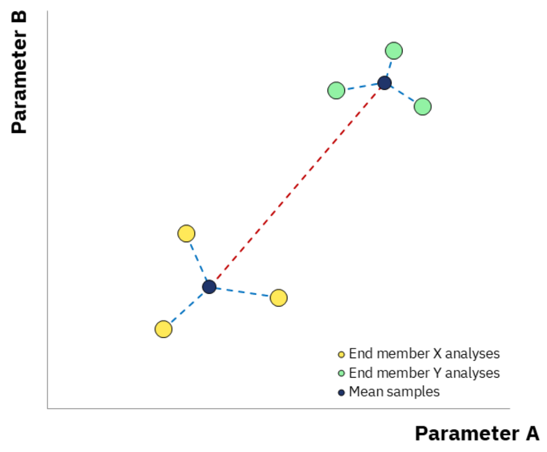


Similar shades of green are hard to distinguish

Data Interpretation Approaches

Data Manipulation – End-members – Replicate Analyses

- Replicate analyses are run to estimate data variability; statistical analyses used to assess variability and select best peaks to give the most reliable results.
- For production monitoring, replicate analyses are used to establish control limits.
- It is insufficient just to provide single-point "best-guess" estimates of end-member contributions. What is the uncertainty in the results? i.e., "plus-minus" confidence intervals:
  - Confidence intervals can be estimated using both Monte Carlo and bootstrap methods.
  - Where adequate numbers of replicate analyses are available, the two methods give similar results; this is encouraging, as bootstrap can be used in cases where replicate analyses are limited or lacking.



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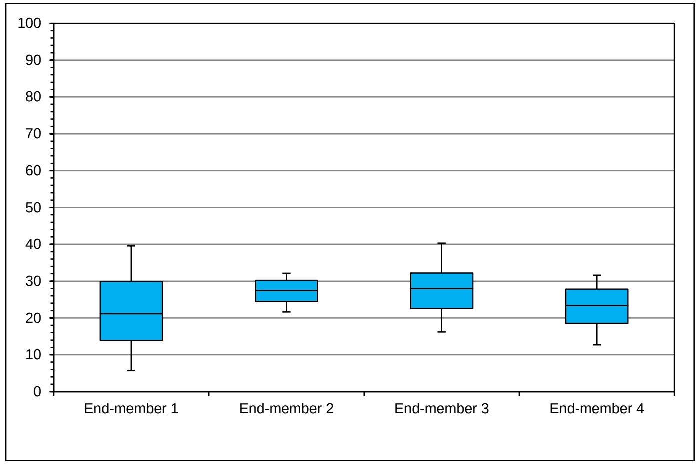
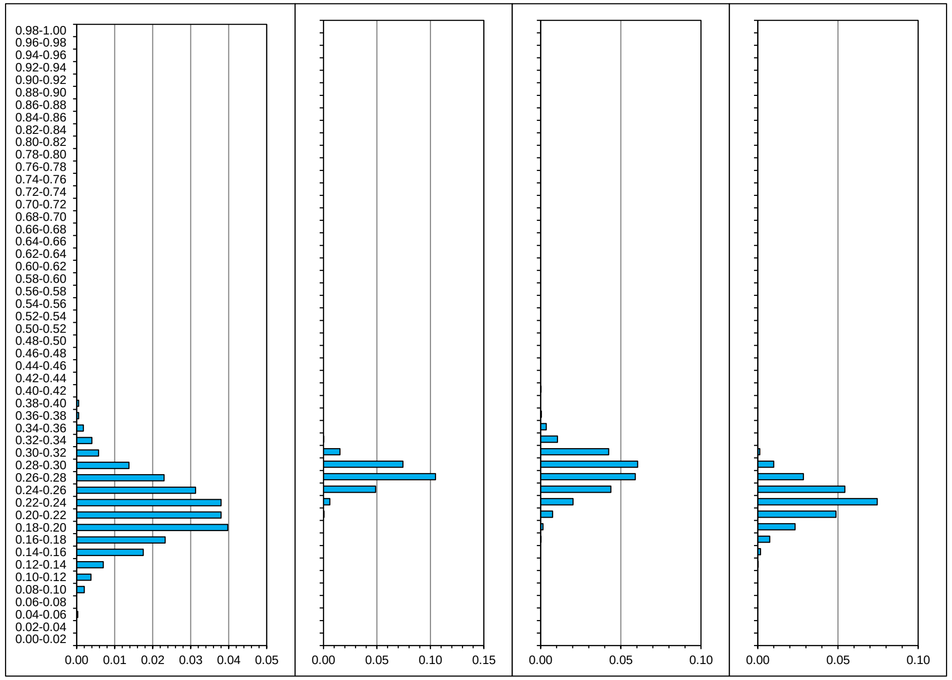
Data Interpretation Approaches

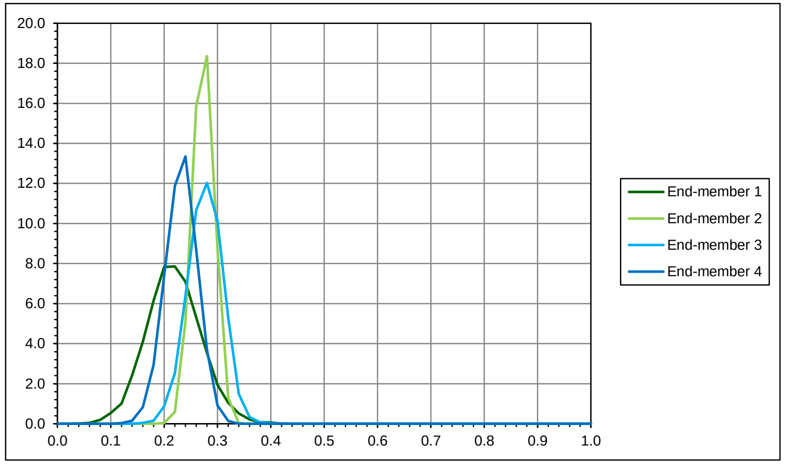
Graphical Presentation of Allocation Results

	1	2	3	4
Best fit	21.18	27.47	27.97	23.37
5%	13.89	24.49	22.59	18.56
95%	29.93	30.21	32.22	27.82
SD (%)	4.98	1.71	3.05	2.80

90% confidence interval
(not a probability)







Workflow Summary

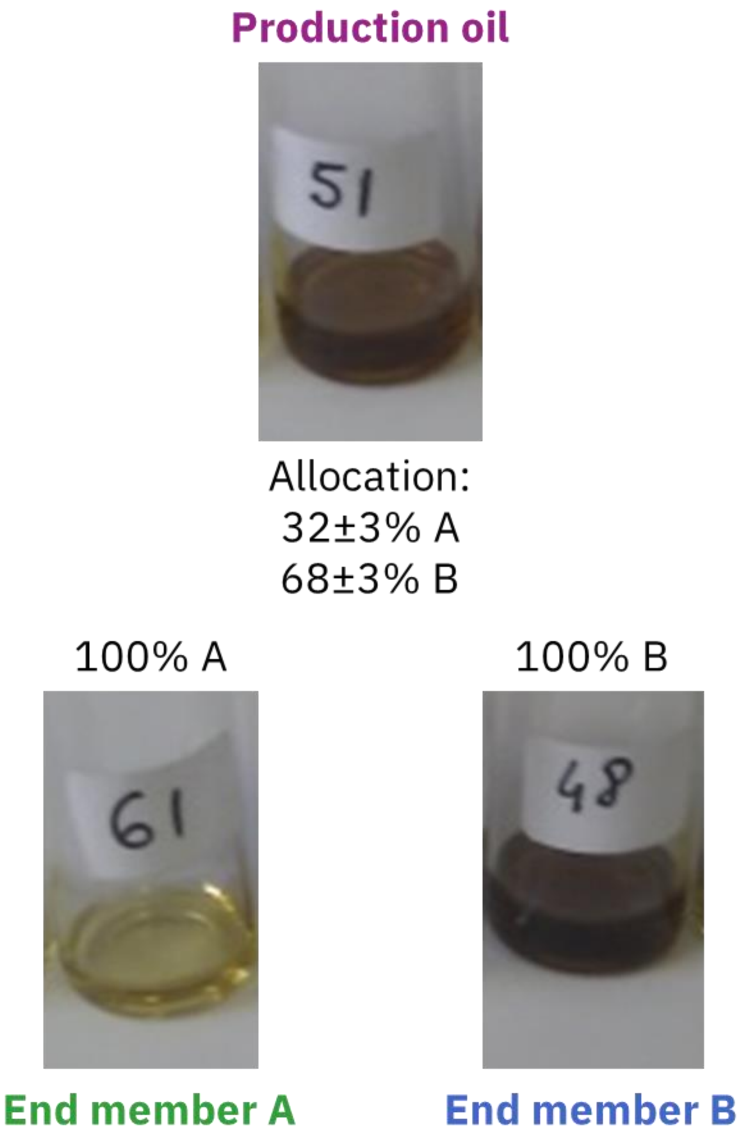
APT Allomon™

Production allocation objective

- Determine the proportions of end-members that constitute a commingled production sample.

Fundamental basis of method

- Some chemical property (concentration, ratio etc.) of a mixture is expressed in terms of the end-members, one equation for each property, resulting in a (possibly large) set of linear equations.



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Workflow Summary

APT Allomon™

1. End members assessed for chemical differences
2. Analytical methods selected for production allocation
   - GC and GCMS are most common.
3. Data selection and pre-processing
   - Optimise data pre-processing, flexible approach, potential benefits of different methods in differing circumstances.
4. End-member contributions to the mixture determined
   - Solve equations (typically many more equations than end-members, so a least-squares "best-fit").
5. Estimate uncertainty, "plus-minus", confidence intervals etc.
   - Monte Carlo simulation (requires replicate analyses to estimate data variance).
   - Bootstrap simulation (replicates desirable but not essential).

Production oil

Allocation:
32±3% A
68±3% B

100% A

End member A

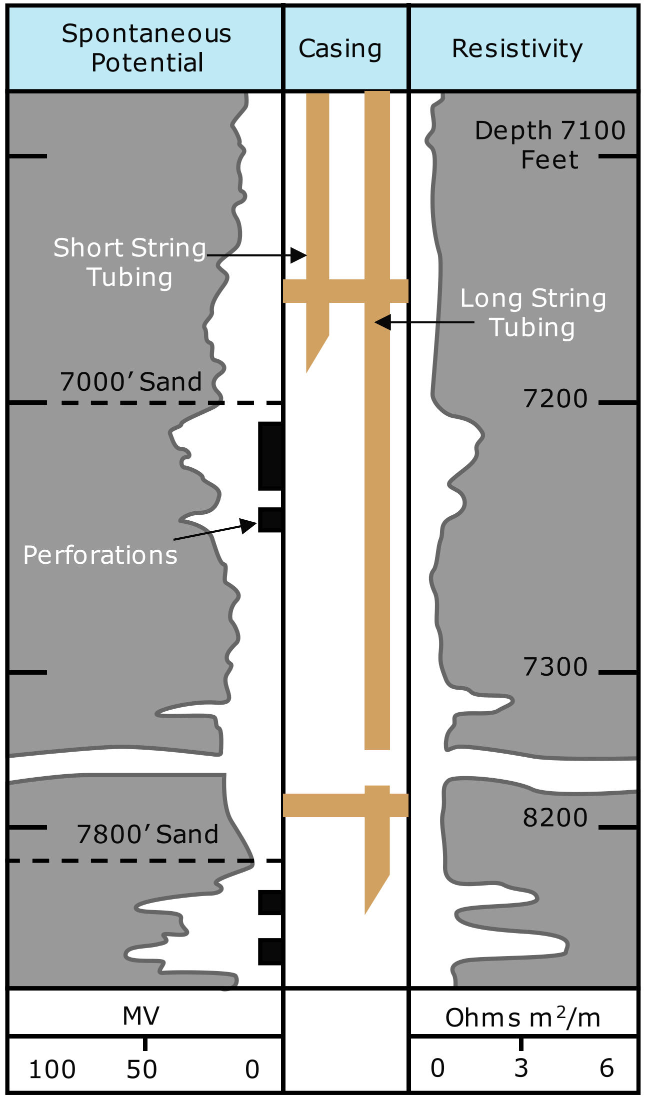
100% B

End member B

Literature Example – Main Pass 299, GOM

Kaufman et al. (1990) – Chevron

- Legal dispute on Main Pass 299, OCS-G-1351-A-2 well (Gulf Coast).
- Dual completion in 7,000 ft. sand and 7,800 ft. sand.
- Both were completed in 1967.
- In 1986, communication between short and long strings was suspected.
- Could geochemical methods be used to determine if and when such mixing occurred?
- Samples taken in 1967, 1972, 1981, 1983, and 1986.

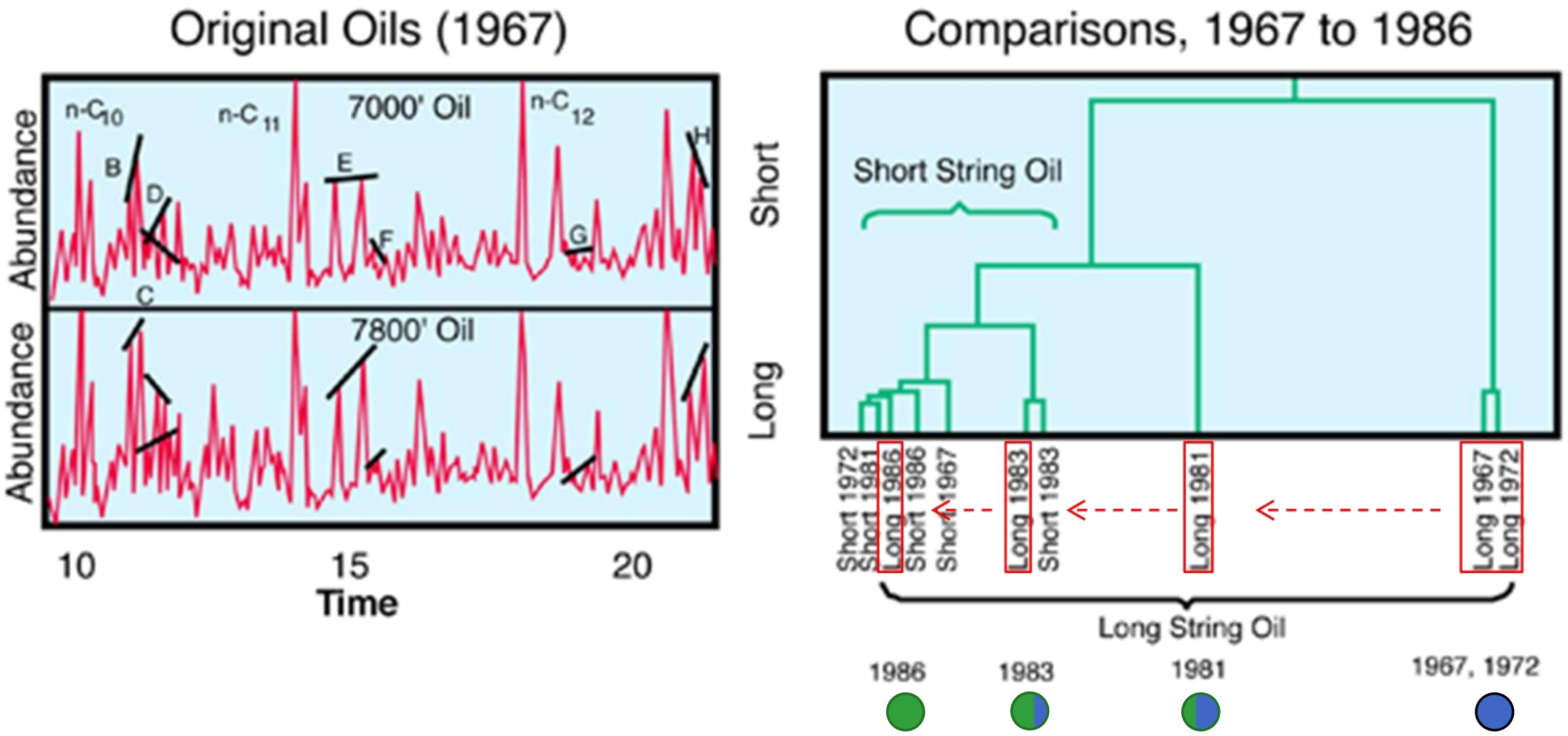


Images modified from Kaufman et al. (1990), GCSSEPM Foundation 9th Annal Conference, pp.263-282

Literature Example – Main Pass 299, GOM

Kaufman et al. (1990) – Chevron

- Short and long strings oils were distinct in 1967.
- Cluster data from Gulf Coast show that oils became similar (i.e., reservoirs began to communicate) between 1981 and 1983.



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Literature Example – Main Pass 299, GOM

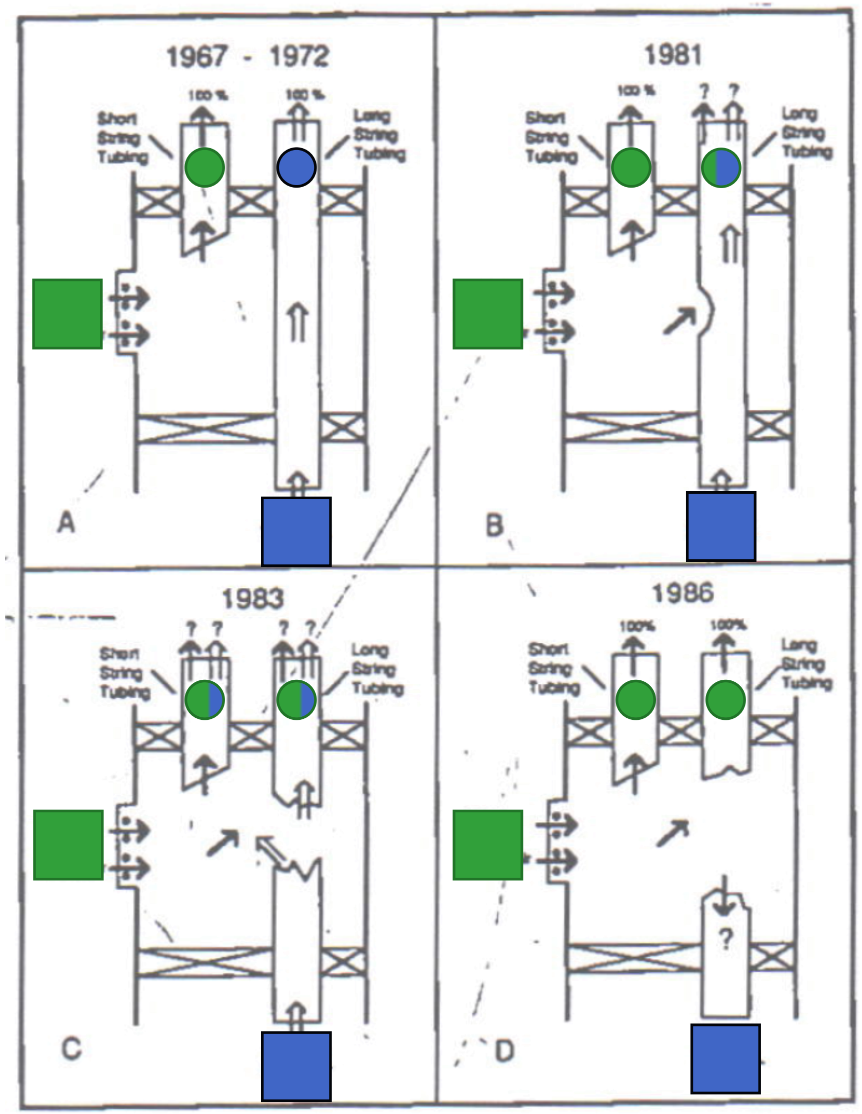
Kaufman et al. (1990) – Chevron

A. 1967 – 1972
- Short string: 7,000 ft. oil
- Long string: 7,800 ft. oil

B. 1981
- Short string: 7,000 ft. oil
- Long string: 7,800 ft. oil mixed with 7,000 ft. oil

C. 1983
- Short string: 7,000 ft. oil mixed with 7,800 ft. oil
- Long string: 7,000 ft. oil mixed with 7,800 ft. oil

D. 1986
- Short string: 7,000 ft. oil
- Long string: 7,000 ft. oil



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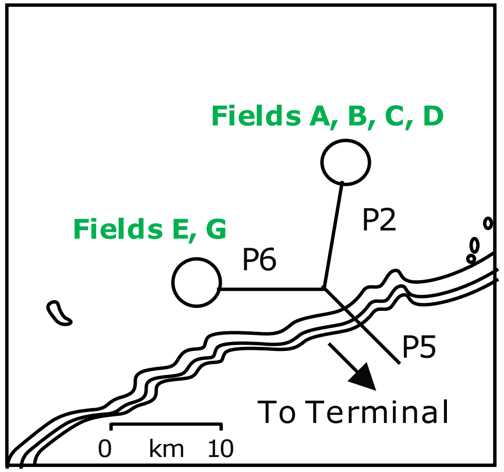
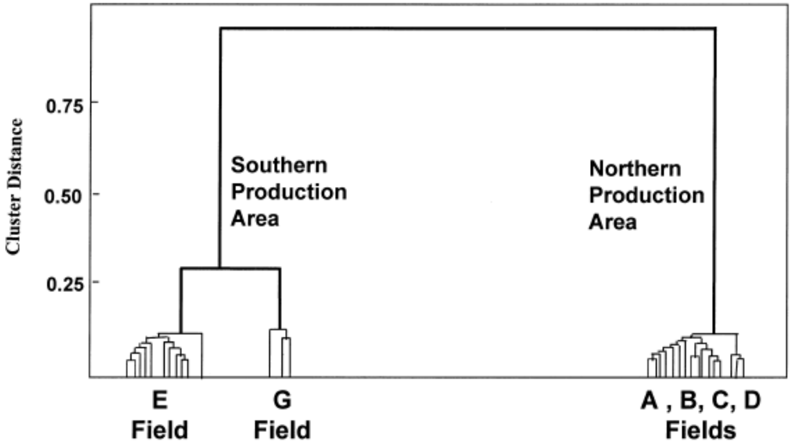
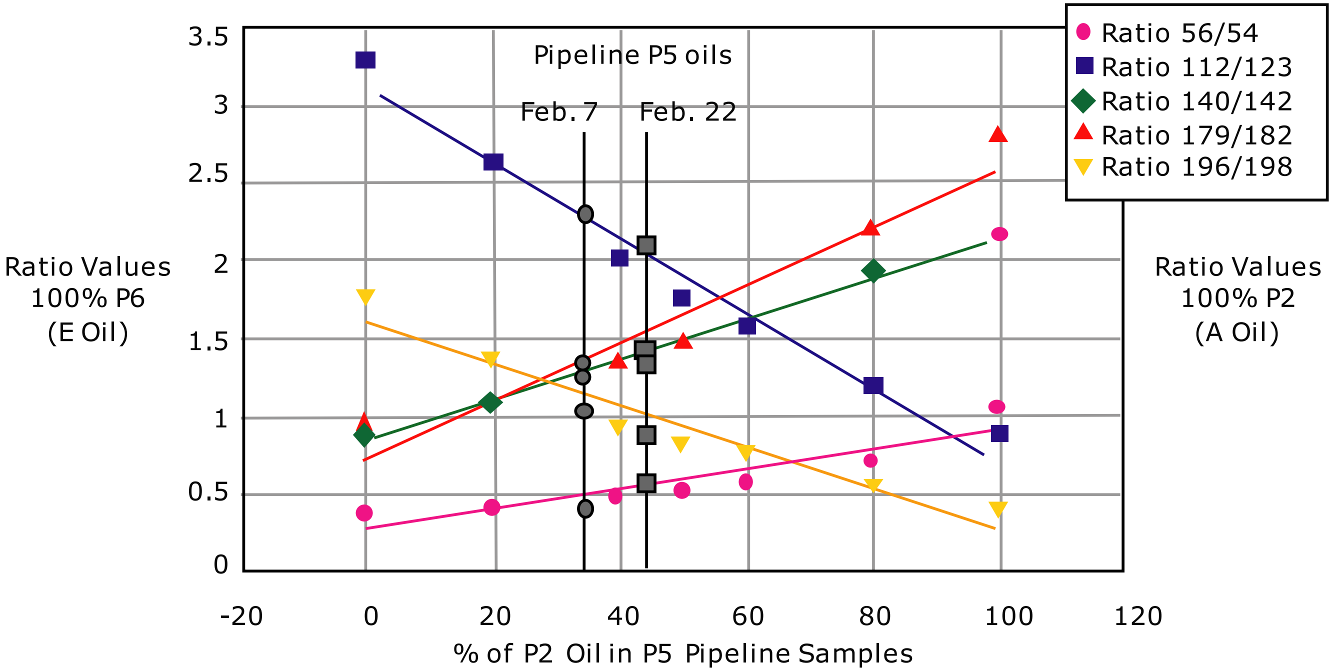
Literature Example – "S.E. Asia"

Hwang et al. (2000) – Chevron



- Oil fields A, B, C, and D have produced **black oil** and taxed as normal.
- Oil fields E and G now produce **gas/condensate**; tax exempt for the first two years.
- Flow meter only installed on pipeline P5.





Images modified from Hwang et al. (2000), Organic Geochemistry 31, 1463-1474

APT Example Norway

Wintershall Dea

Goal:

- To distinguish the oils in the Fensfjord, Sognefjord, Statfjord, Cook, Ness

Wells:

- Many

Issues:

- Many samples have suffered extreme loss of light ends (up to C20) in storage that has affected gasoline range ratios and makes grass peak analysis problematic.
- Cook samples are from only one well and have drilling fluid contamination.
- Ness samples are from only one well.
- Well uncertainty in a few cases.

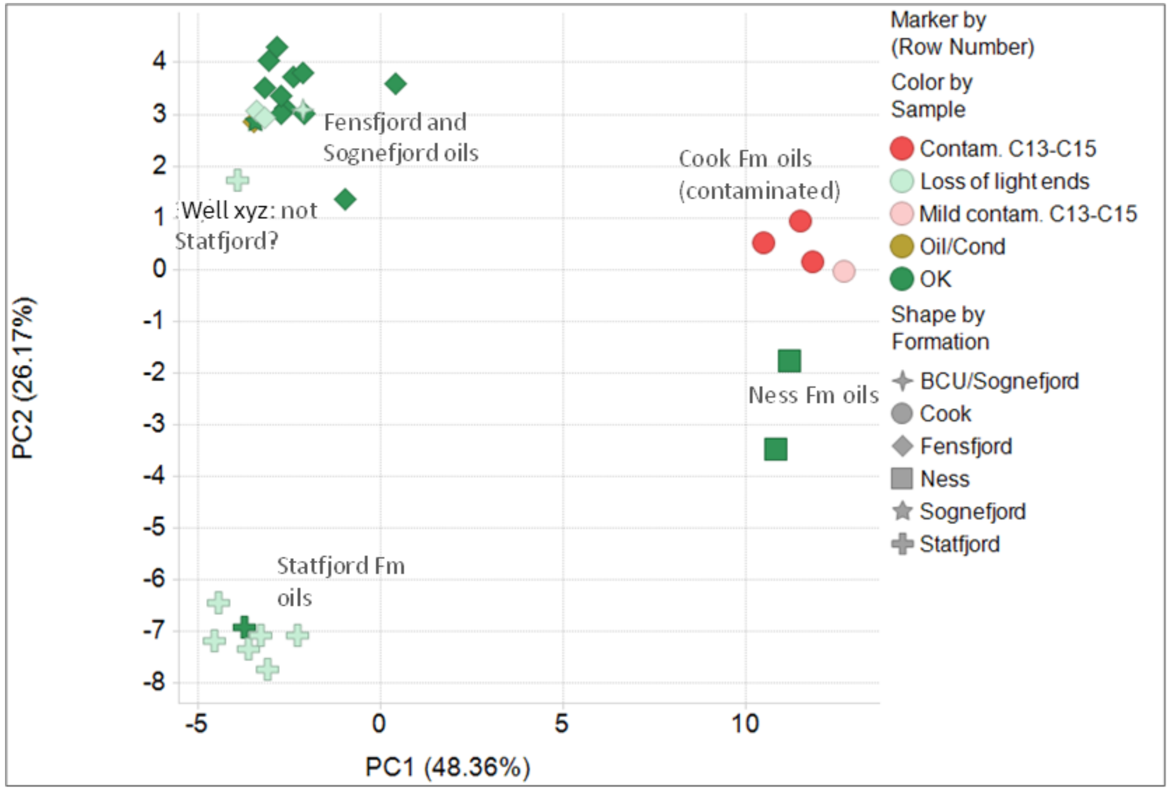


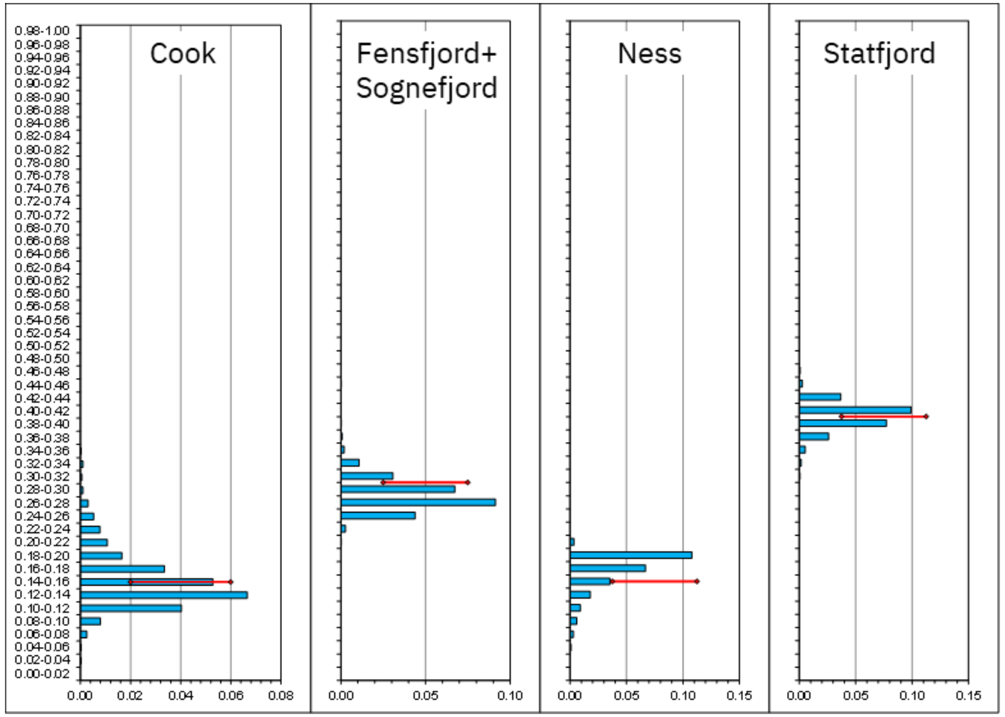
Image modified from Garlichs et al. (2021), IMOG 2021, https://doi.org/10.3997/2214-4609.202134106

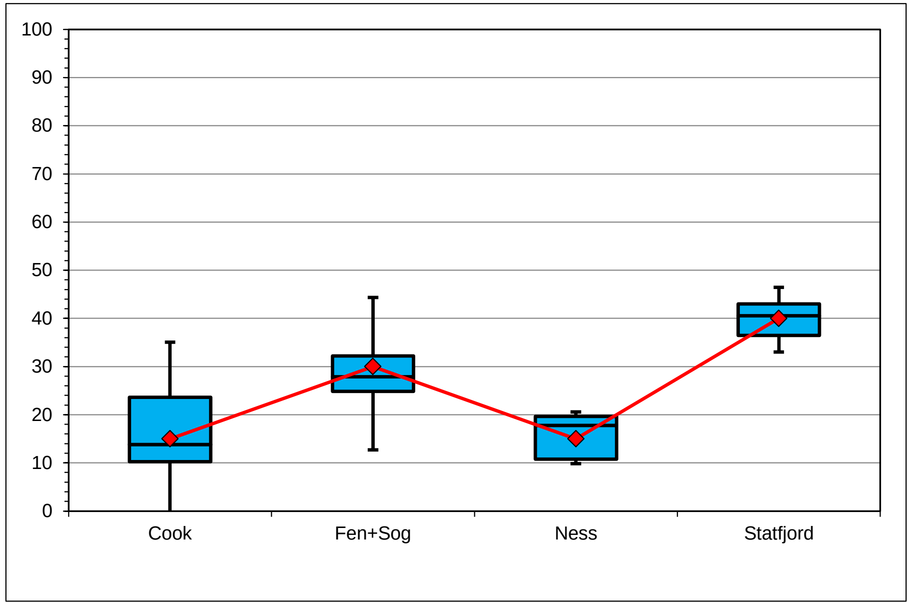
APT Example Norway

Wintershall Dea

- Blind test with artificial mixture

	Cook	Fensfjord + Sognefjord	Ness	Statfjord
Known mixture	15.00	30.00	15.00	40.00
Best fit	13.84	27.87	17.76	40.53
5 % confidence	10.27	24.82	10.79	36.46
95 % confidence	23.64	32.20	19.65	43.01
SD (%)	4.16	2.37	2.83	2.03





Production Allocation and Monitoring

- APT can provide a highly individual service, tailored to meet the unique field circumstances and client requirements.
- No "one size fits all" approach – multiple analytical, data processing and statistical approaches available.
- Highly experienced chemists, geochemists and geologists with decades of experience of solving geological problems, data manipulation and statistical processing and modern, well-equipped laboratories with proven long-term data reliability/reproducibility.
- In house software which can utilise different mathematical approaches to quantitative allocation.

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