AI in Action:
Five Challenging Case Studies

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Outline

- Artificial Intelligence (AI) and Machine Learning
- 5 Case Studies showing successful applications
  - Nuclear Magnetic Resonance T1 & T2 spectra analysis
  - Prediction of shear velocities
  - Litho-facies and permeability prediction
  - Evolution of shaly water saturation equations
  - The log quality control and repair of electrical logs

Artificial Intelligence only requires Two Things

1. You tell the AI what you want
   - This is its goal or fitness function

2. The data

There's Minimal human interaction

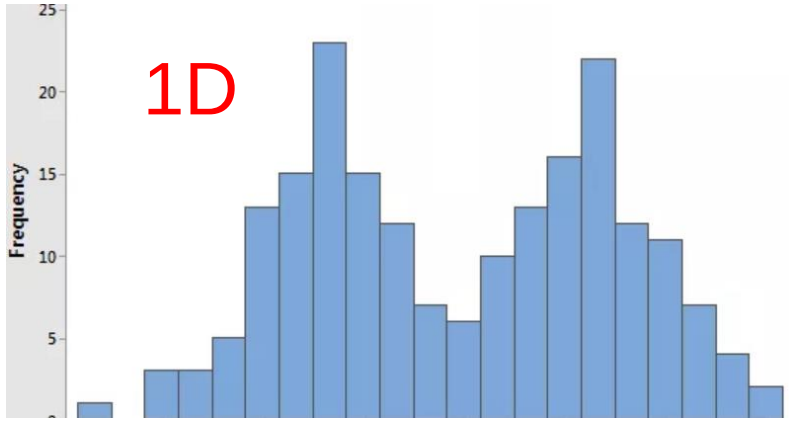
- AI doesn't require prior knowledge of the petrophysical response equations
- There are no parameters to pick or cross-plots to make

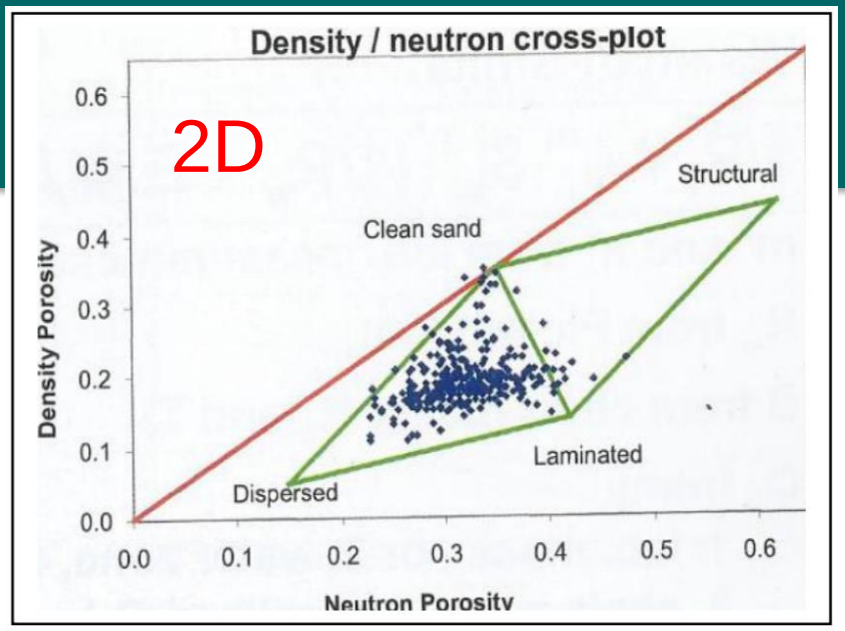
AI is given access to all the data

These include:

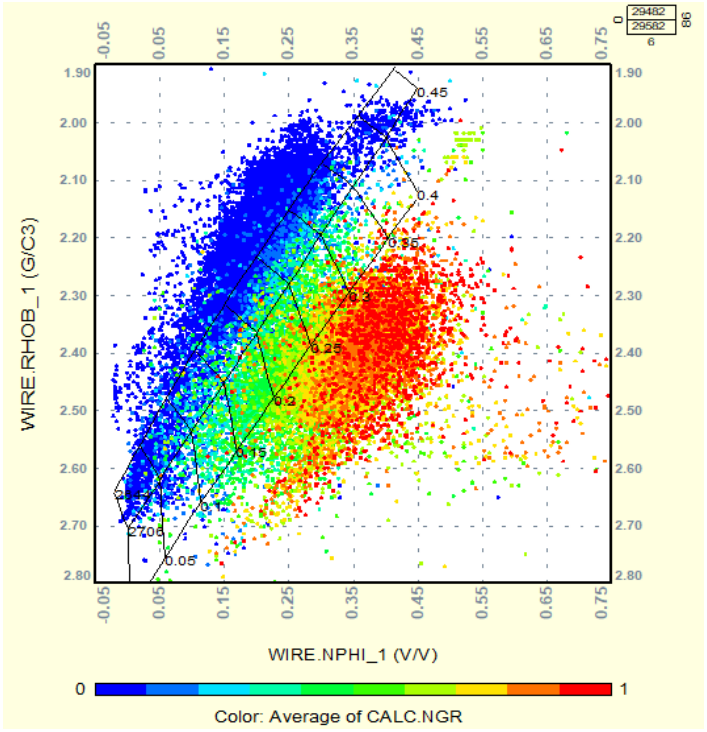
- Electrical logs - GR, Rhob, caliper, drho etc.
- Core data - porosity, core Sw, SCAL etc.
- Depth - measured and TVDss (probably the most important parameters)
- Gas - chromatography data (essentially a free measurement)
- Drilling data - ROP, Dexp etc.
- NMR - T1 & T2 distributions (spectra)
- etc.
  - Don’t worry if these data contain garbage, as explained later
  - Loaded into the AI as n-dimensional data

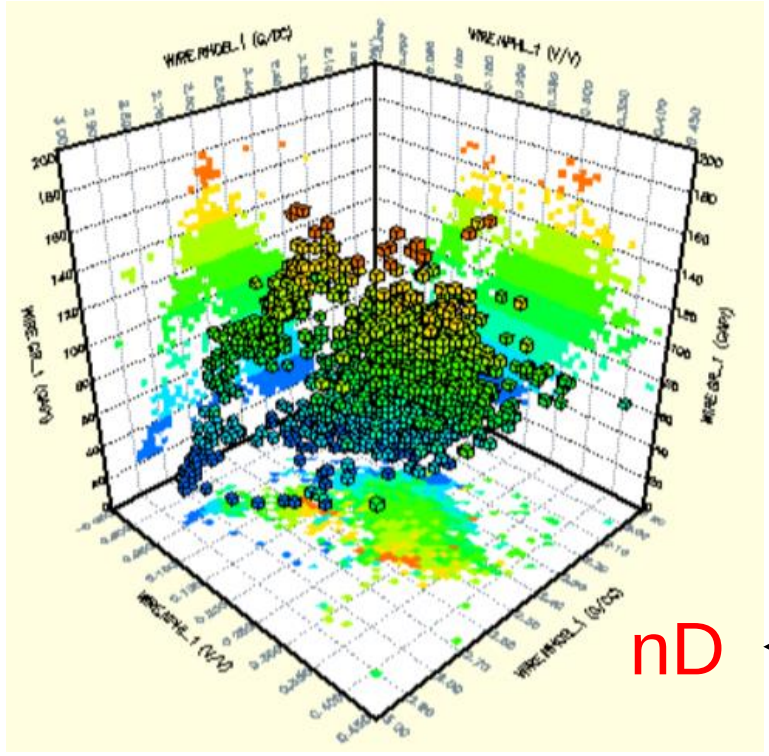
What is n-dimensional Data?





3D





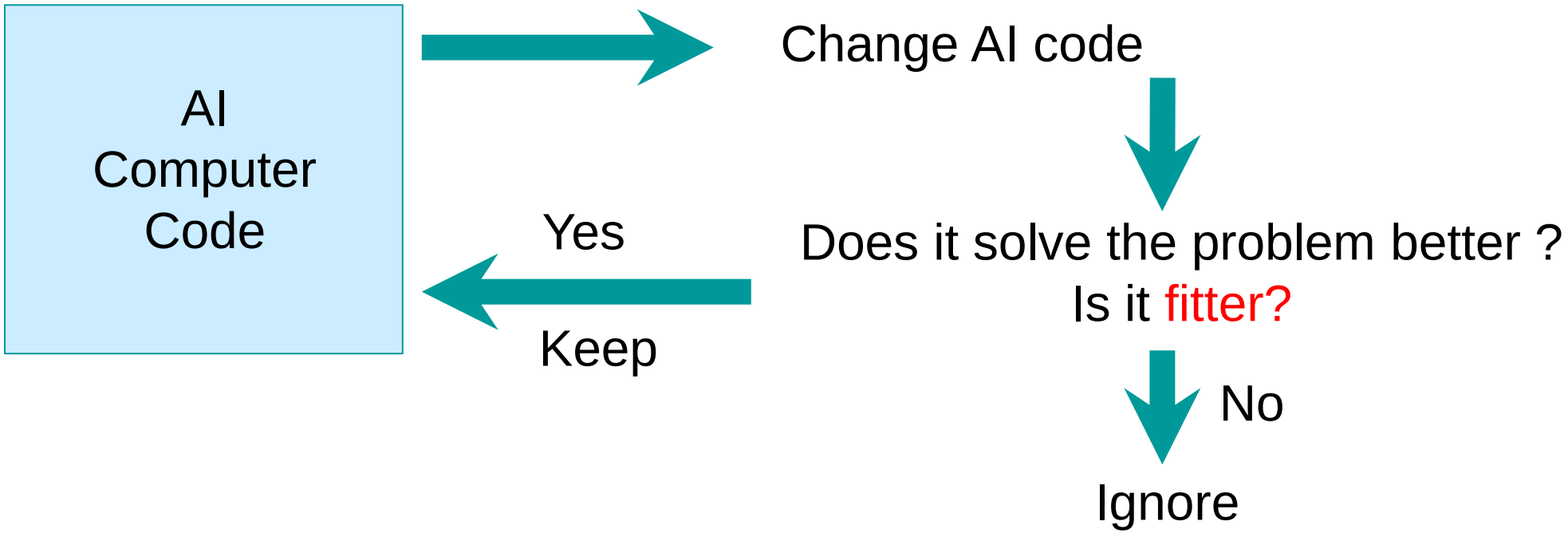
Relational database where n is the number of logs and other inputs

AI Engine

- AI is data analysis that learns from data, identify patterns and makes predictions with the minimal human intervention
- AI uses neural networks, genetic algorithms, fuzzy logic, random forests
- AI avoids Garbage In, Garbage Out (GIGO) by
  - good data swamping poor data
  - by using fuzzy logic (modified Bayesian statistics)

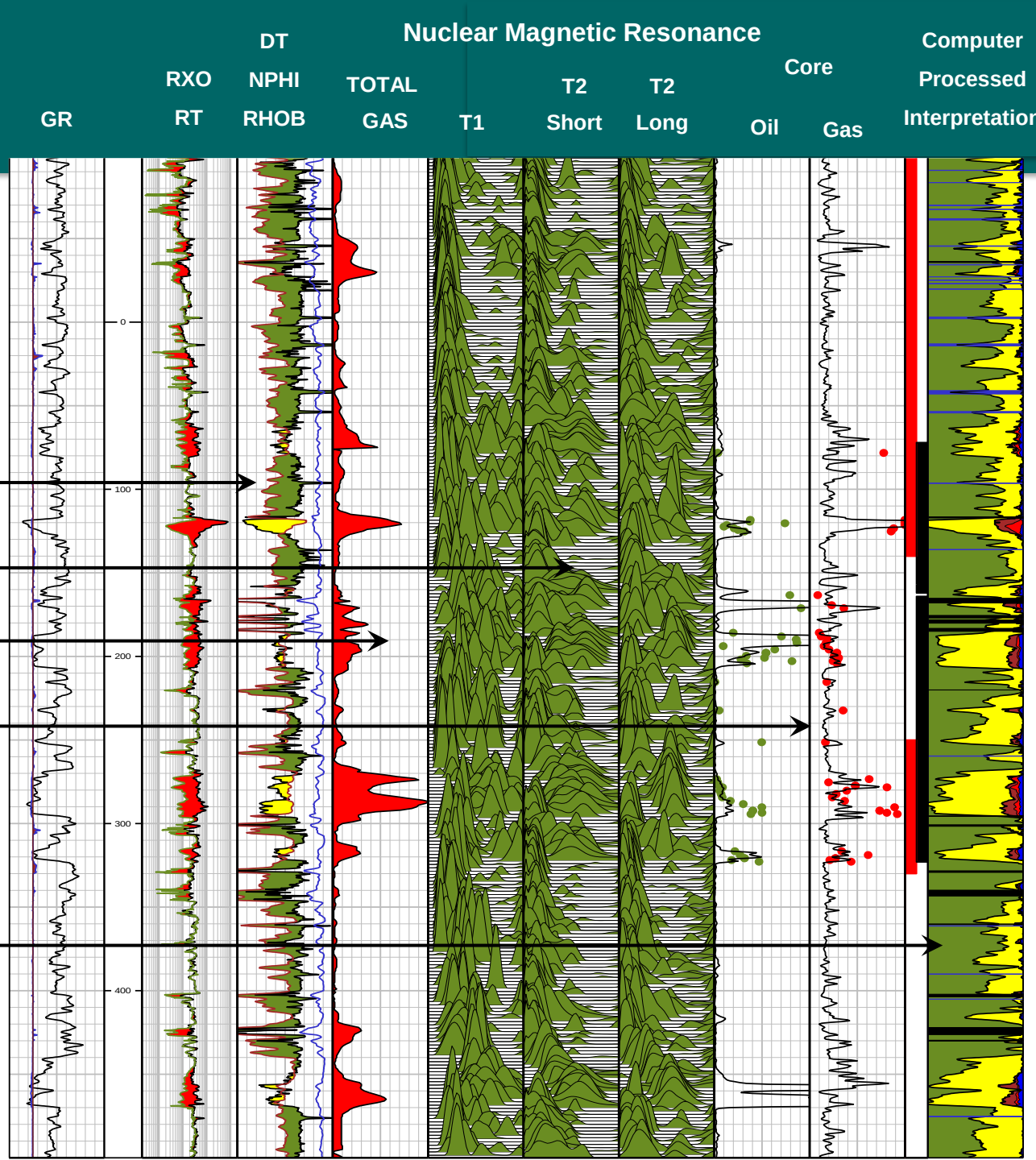
AI

- We define the problem - Fitness Function
- We give the program access to the data
- The computer works through successive iterations ‘evolves’ the best answer



NMR Pattern Recognition

- Case Study
  - A gas field with an oil problem
- Data:
  - Conventional logs
  - NMR T1 and T2
  - Gas Chromatography
  - Core derived oil and gas saturations
- Petrophysical analysis

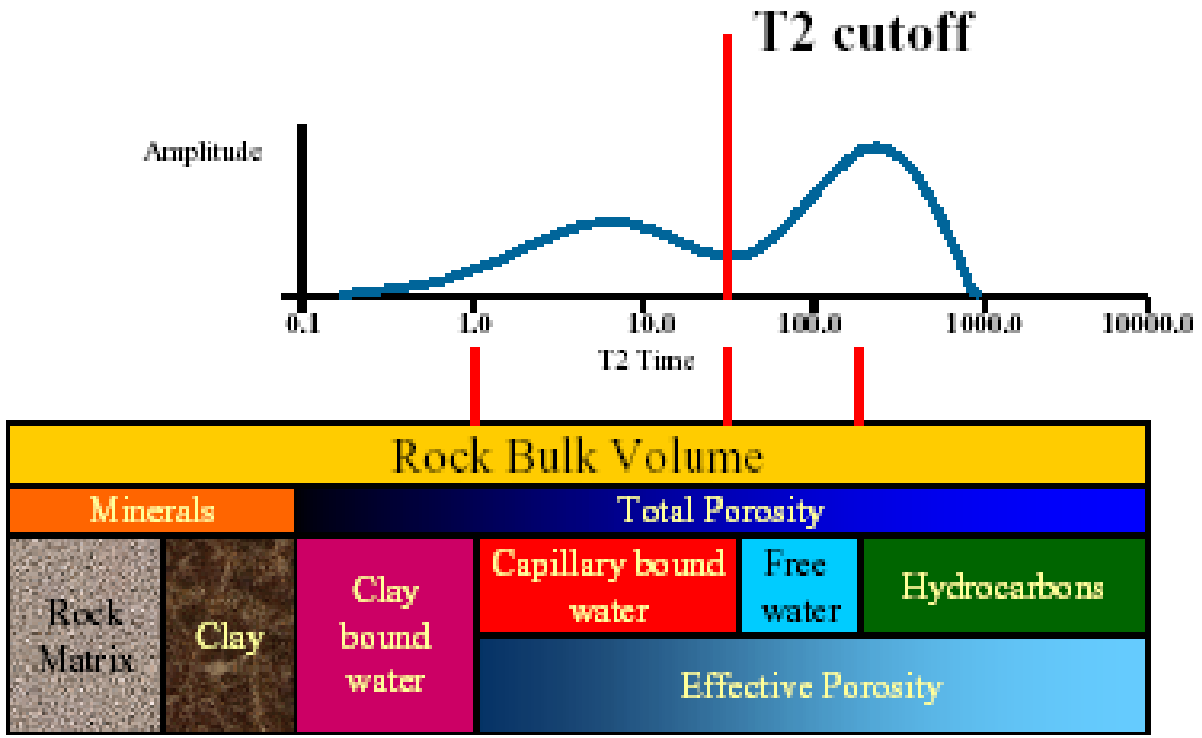


Shale
Sandstone
Limestone
Gas / Oil
Water

Case Study 2 – NMR Pattern Recognition

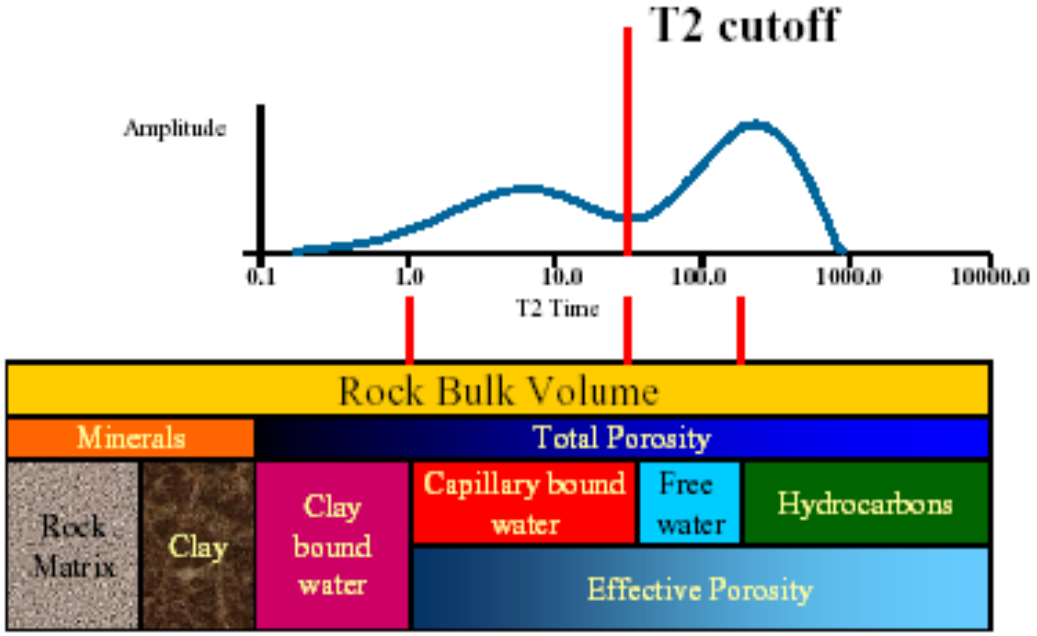
- A gas field with an oil problem
- Residual oil pockets remain within the main gas reservoir
- This oil is highly viscous
- If produced could block the production tubing
- The client needs to identify oil and gas in order to only perforate the gas zones
- Conventional petrophysical techniques like density / neutron porosity separation can’t differentiate oil and gas due to thin beds and the shaly formation

Nuclear Magnetic Resonance



- The solution lies with nuclear magnetic resonance (NMR)
- Essentially this measures how hydrogen atoms respond to a magnetic field

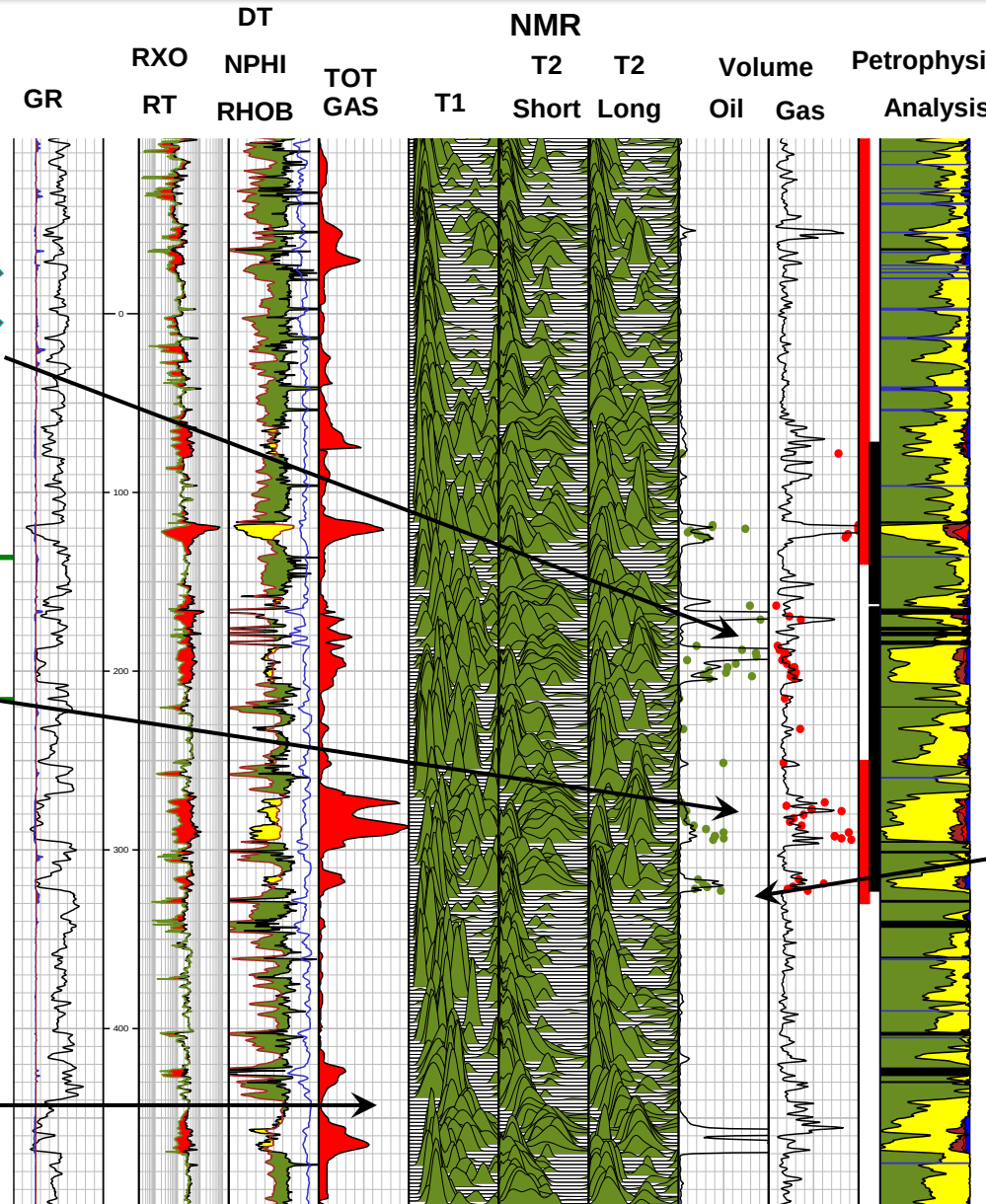
Oil and Gas identification using the NMR and AI



- AI determines the NMR waveforms associated with the core derived oil and gas analysis, in a similar way to how face recognition algorithms work
- It then predicts the fluid content of all the reservoir beds
- Fitness Function: ‘Determine the waveforms that give the best match to the core derived oil and gas saturations in the reservoir’

Results – Real time identification of gas and oil zones

- NMR identified intervals of high oil saturations and low gas saturations
  - These were not perforated
- NMR identified intervals of low oil saturations and high gas saturations
  - These were perforated
- These intervals were confirmed using the borehole fluid analyser and borehole gas chromatography



Shale
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NMR 'face recognition' predicted continuous oil and gas saturations as shown in these 2 tracks

Fuzzy Logic (Modified Bayesian Statistics)

- An extension of the classical logic of 0 and 1
  - uses a ‘grey scale’ between 0 and 1
- Fuzzy logic looks for correlations in data space
  - asserts there is valuable information in the fuzziness (1/crispness)
  - avoids the problems of outliers and noise
- Fuzzy logic says any petrophysical interpretation is possible
  - only some interpretations are more likely than others

The AI Engine

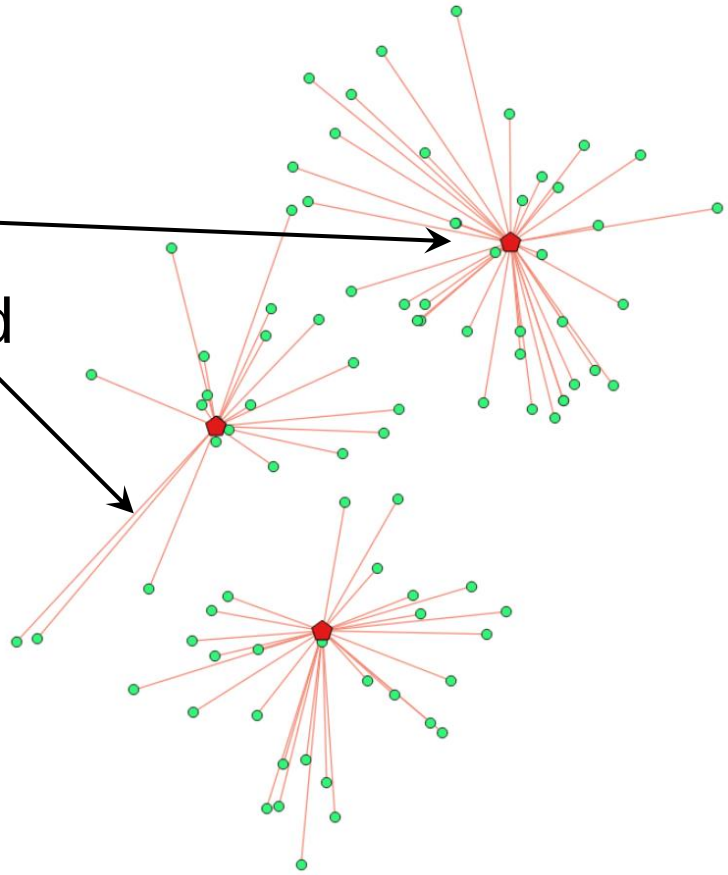
• In n-dimensional data space, the k-NN algorithm assumes that similar things exist in close proximity or nearest neighbour

- e.g. litho-facies - sand, shale or carbonate

• The straight-line distance (the Euclidean distance) is used

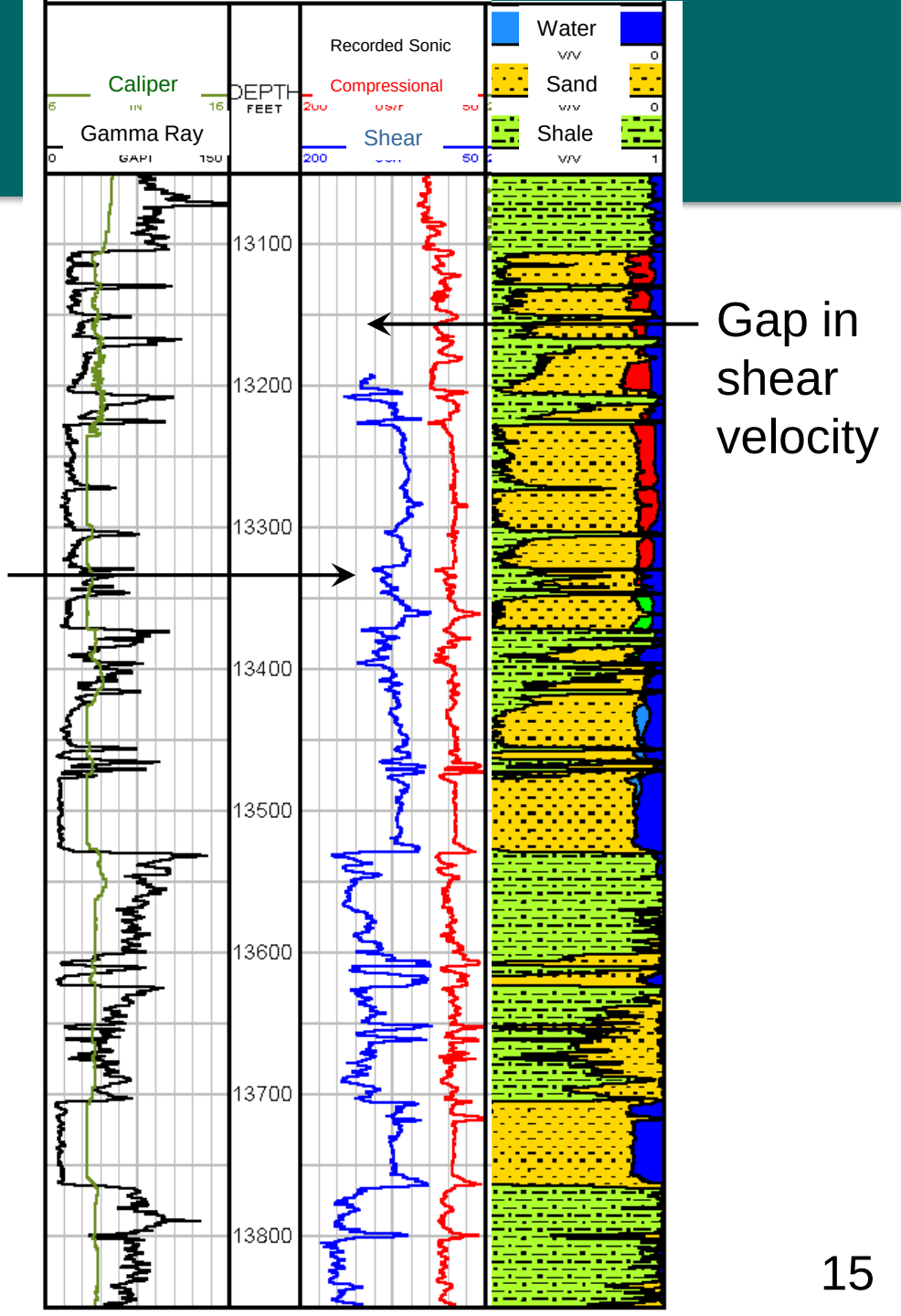
- in addition, fuzzy logic weights these lines depending on the likelihood of the association

• For instance, if the gamma-ray is highly correlated (crisp) with shaliness, this vector will have more influence on the AI's decision compared to say the caliper reading at the same depth



Shear Velocity Prediction using AI

- Case Study
  - North Sea Field
- Only four wells had recorded shear velocity data
- Shear velocity was required on all 30 wells
  - for rock property analysis
  - wellbore stability
- Gaps and cycle skips need to be fixed



Shear Velocity Prediction using AI

Fitness Function – ‘Determine a relationship so that the predicted shear velocities are as close as possible to log derived shear velocities’

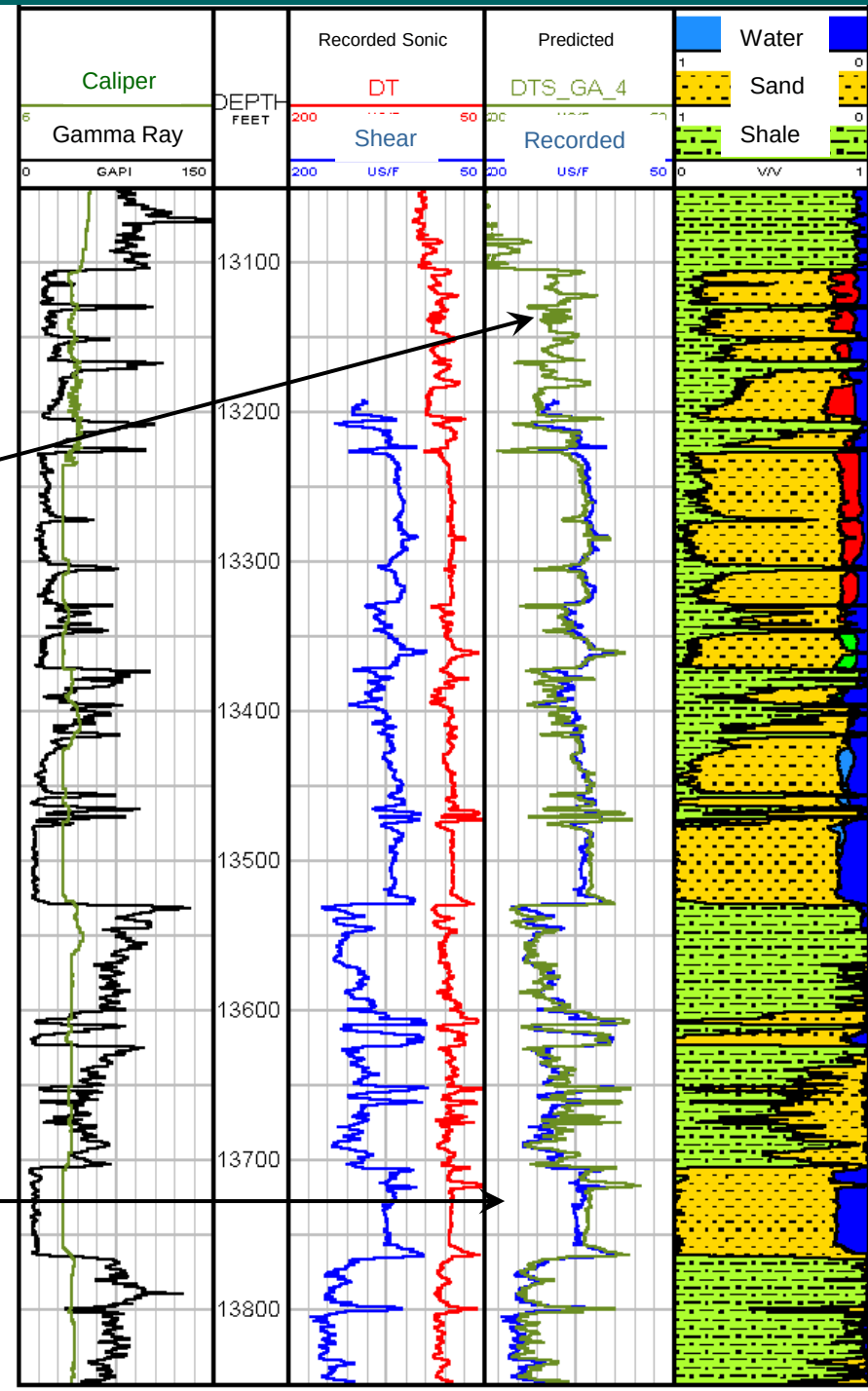
Predicted shear velocity = Function of:

- conventional logs
- drilling data
- gas chromatography data

The AI evolves the relationship

The AI predictions are better than the recorded logs!

- because AI has access to all logs, including logs with high vertical resolution like the micro-resistivity



Advantages of using AI in Petrophysical Analysis

- AI doesn’t require prior knowledge of the petrophysical response equations
- AI is self-calibrating. Just give it the data
- AI avoids the problem of ‘Garbage In, Garbage Out’,
  - by ignoring noise and outliers
- There is very little user intervention
  - There are no parameters to pick or cross-plots to make
- AI programs work with an unlimited number of electrical logs, core and gas chromatography data; and don’t ‘fall-over’ if some of those inputs are missing
- AI is not a Black Box, as it provides insights into how it makes predictions

AI Requirements

- Data
- Fitness Function
  - Tells the AI what you want it to do
  - Written in plain English
  - Question - Does the AI understand what you really want?

The Fitness Function

- King Midas, in Greek mythology, was granted his wish that everything he touched turned into gold
- He didn’t realise that this included his food and his children
- Similarly, an ill-conceived Fitness Function may give unexpected results

Conclusions

- AI and Machine Learning makes petrophysical analysis easy
  - supports rather than replaces the petrophysicist
- All 5 case studies and AI logic
  - Cuddy, S. (2021) The benefits and dangers of using artificial intelligence in petrophysics. Artificial Intelligence in Geosciences
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