Predicting Porosity and Hydrocarbon Saturation of Rock Formations During Drilling Using Genetic Algorithms & Fuzzy Logic

Alexandra D. Pinto de ANDRADE, Stephen J. CUDDY & Paul W.J. GLOVER

University of Aberdeen & PetroInnovations

Structure

- The Role of Improved Data Analysis in Minimising the Impact of Hydrocarbon Extraction
- The Problem of Porosity and Hydrocarbon Saturation Prediction
- Cuttings Gas Logs & Genetic Algorithms
- A Field Example
- Summary

Minimising Environmental Impact

- **Can take many forms**
  - ➔ Remediation of current pollution
  - ➔ The limitation of spills at refineries
  - ➔ Improved methods of transporting oil
  - ➔ Improved rig decommissioning
  - ➔ The reduction and prevention of pollutant gas emission
  - ➔ Extending current field life using improved analysis techniques
  - ➔ Improvements to the design of drilling and production rigs
  - ➔ Improved seismic methods to reduce their impact upon the sea-life

The Problem

- Improved analysis of reservoirs depends on accurate knowledge of the porosity and hydrocarbon saturation at depth
- Expensive, time-consuming well log techniques are used
- These techniques can be environmentally damaging

Cuttings Gas Logs - What Are They?

- **The log of the different hydrocarbon gases evolved from drilling cuttings**
  - **➔Are done in every well during drilling**
  - **➔Are a statutory obligation on the grounds of safety**
  - **➔Are therefore "free" and immediately available**
- **They have an extremely poor vertical resolution**
- **They have not been successfully linked to useful reservoir properties such as porosity and saturation**

Cuttings Gas Logs - Types

- **Commonly the lighter alkanes are analysed**
  - **C1, C2, C3, iC4, nC4, C5, C5+**
- **Sometimes expressed as gas ratios**
  - **Hydrocarbon Wetness (W_h)** $$Wh = \frac{(C_2 + C_3 + C_4 + C_5)}{(C_1 + C_2 + C_3 + C_4 + C_5)} x\,100$$
  - **Hydrocarbon Balance (B_h)** $$Bh = \frac{(C_1 + C_2)}{(C_3 + C_4 + C_5)}$$
  - **Hydrocarbon Character (C_h)** $$Ch = \frac{(C_4 + C_5)}{C_3}$$

Genetic Algorithms (GAs) - What Are They?

- **Computer-based**
- **Take a general form of an equation**
- **Evolve the equation constants and operators until a best fit to some calibration data is found**
- **The evolution may include random changes, cloning, sexual reproduction etc.**
- **The evolved equation uncovers the mathematical relationships hidden in the calibration data**
- **The equation can be used to predict any desired parameter**

Genetic Algorithms - The Equation

- **General Form**

$$Y(A, B, C, D\ldots) = aA^b \diamondsuit_1 cB^d \diamondsuit_2 eC^f \diamondsuit_3 gD^h \diamondsuit_4 \ldots$$

where:

$\diamondsuit_i$ = Either + , - , ÷ or ×

a, b, c, d, e, f ... are constant parameters

A, B, C, D … are variables in the calibrating data set

Y(A, B, C, D…) is the parameter that is required

Genetic Algorithms - Uses

- **Can discover the mathematical relationship linking complex patterns**
- **Can be used to predict the porosity and saturations in the sub-surface from well-log data**
- **But also from any data that contains information about porosity and saturation no matter how complex or slight the relationship**
- **If CGLs contain information, GAs will find it**
- **Then porosity and saturation can be predicted**

GA - Example

Input (Calibration Data)

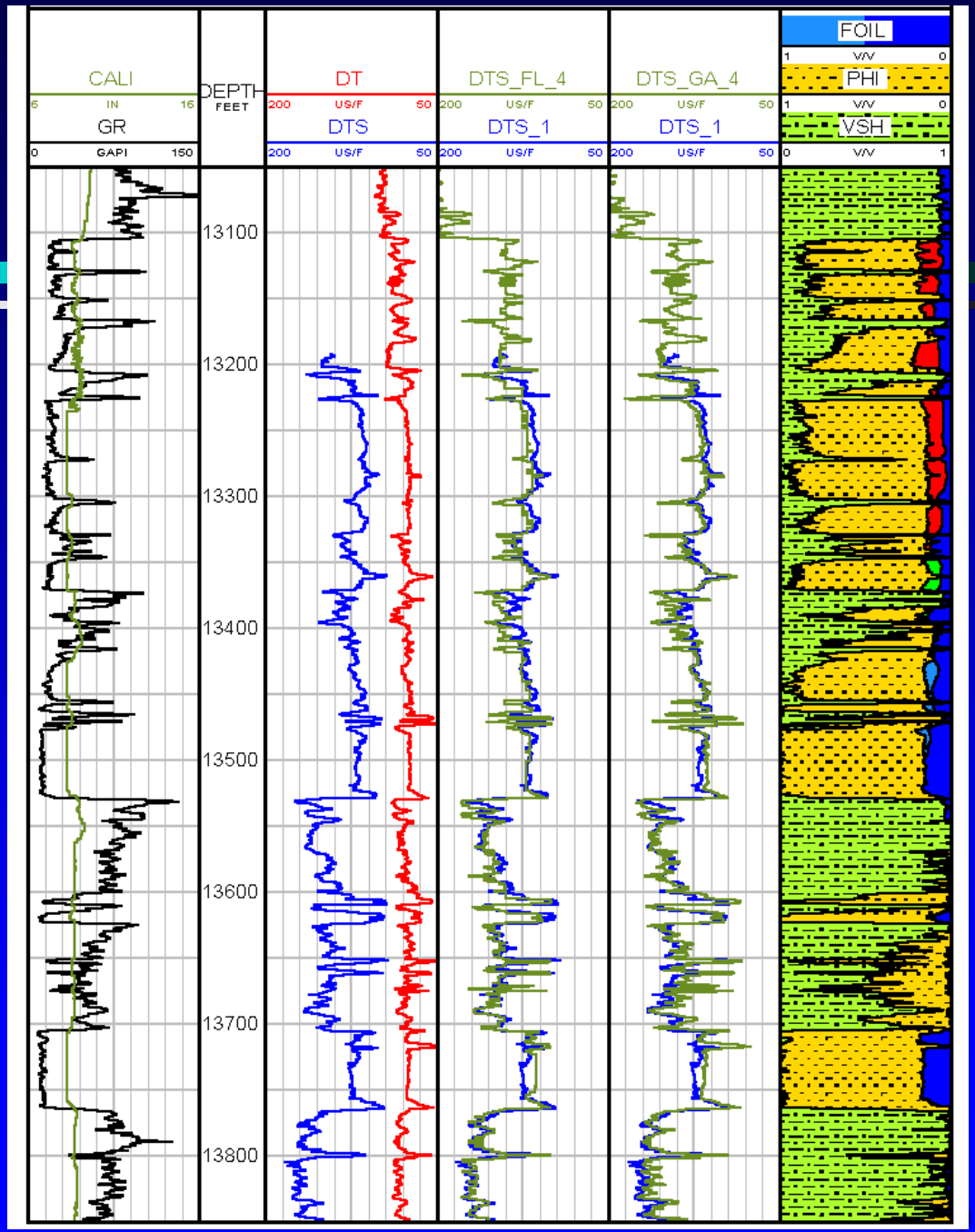
- CALI
- GR
- DT

Output (Predicted Data)

- DTS_GA_4
- DTS_FL_4

Test (Comparison Data)

- DTS
- DTS_1



The Use of Cuttings Gas Analysis and Genetic Algorithms to Predict the Porosity and Hydrocarbon Saturation

A Field Example

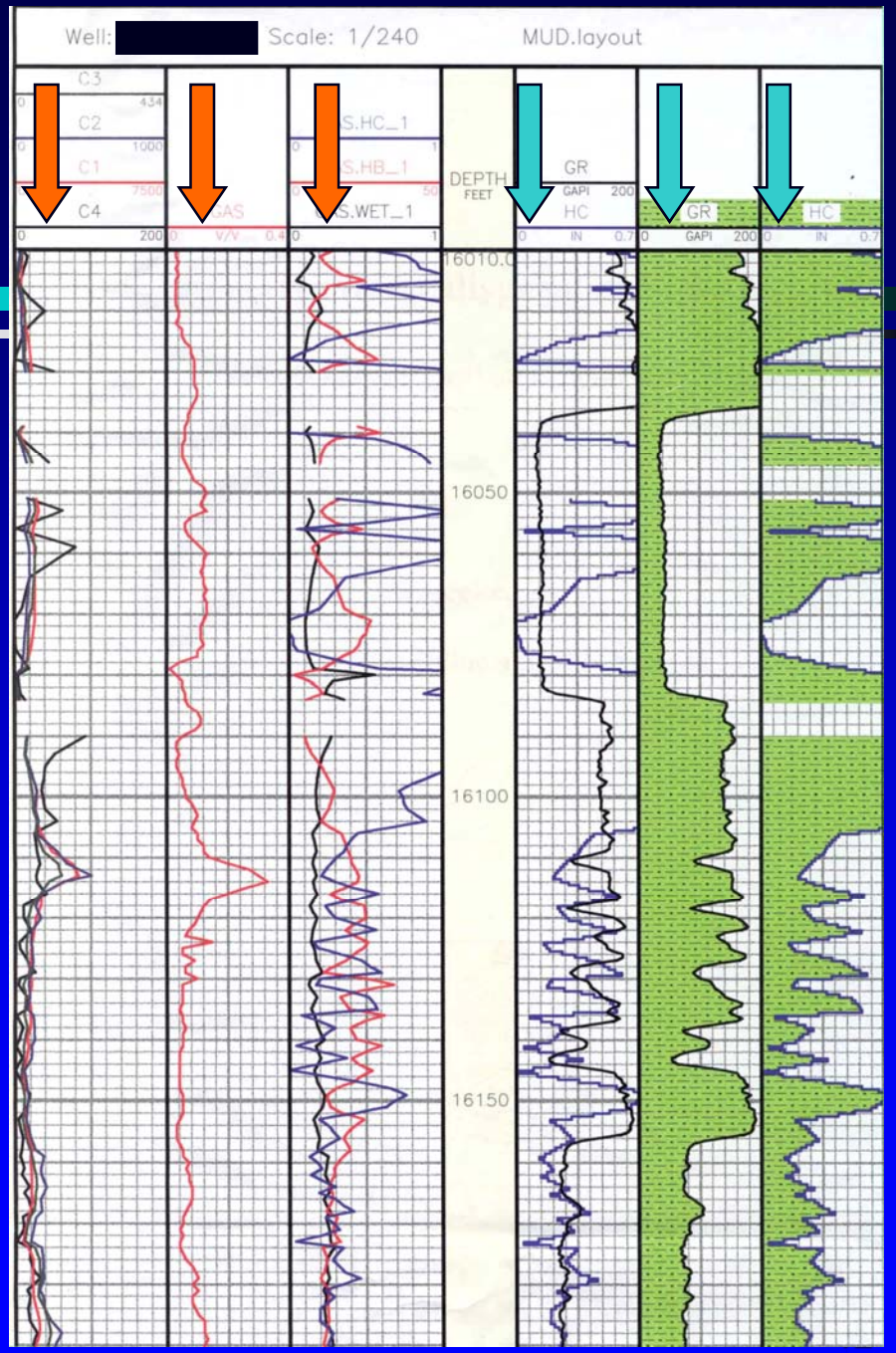
Results I

Gas Data

- Individual Cuttings Gas: Track 1
- Total Gas: Track 2
- Cuttings Gas Ratios: Track 3
  - Hydrocarbon Character (HC)
  - Hydrocarbon Balance (HB)
  - Hydrocarbon Wetness (WET)

Comparison of Hydrocarbon Character Ratio with Gamma Ray

- GR and HC Ratio: Track 4
- GR alone (filled): Track 5
- HC alone (filled): Track 6



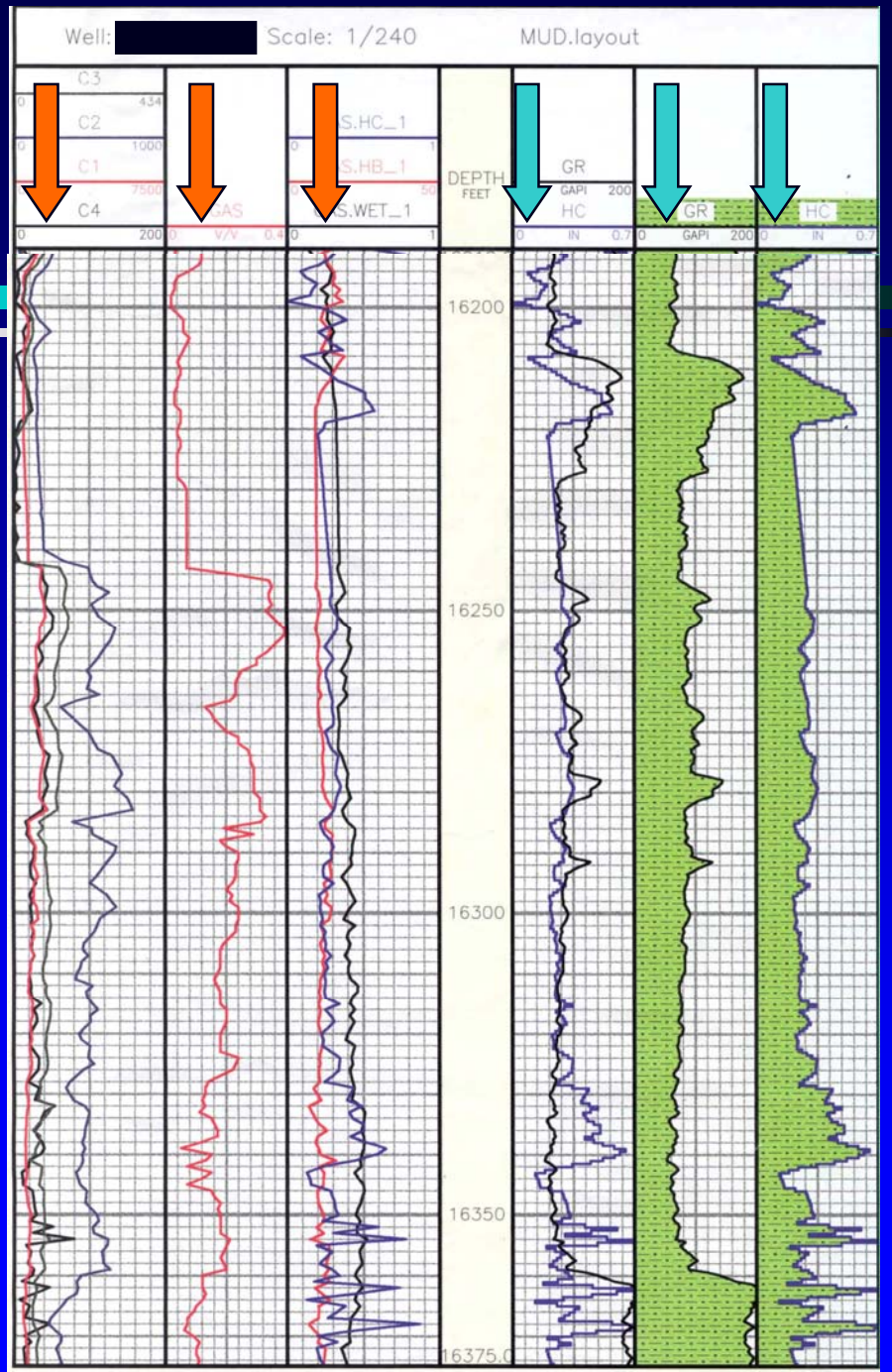
Results II

Gas Data

- Individual Cuttings Gas: Track 1
- Total Gas: Track 2
- Cuttings Gas Ratios: Track 3
  - Hydrocarbon Character (HC)
  - Hydrocarbon Balance (HB)
  - Hydrocarbon Wetness (WET)

Comparison of Hydrocarbon Character Ratio with Gamma Ray

- GR and HC Ratio: Track 4
- GR alone (filled): Track 5
- HC alone (filled): Track 6



Results III

Track 1: Comparison of HB with Density Log

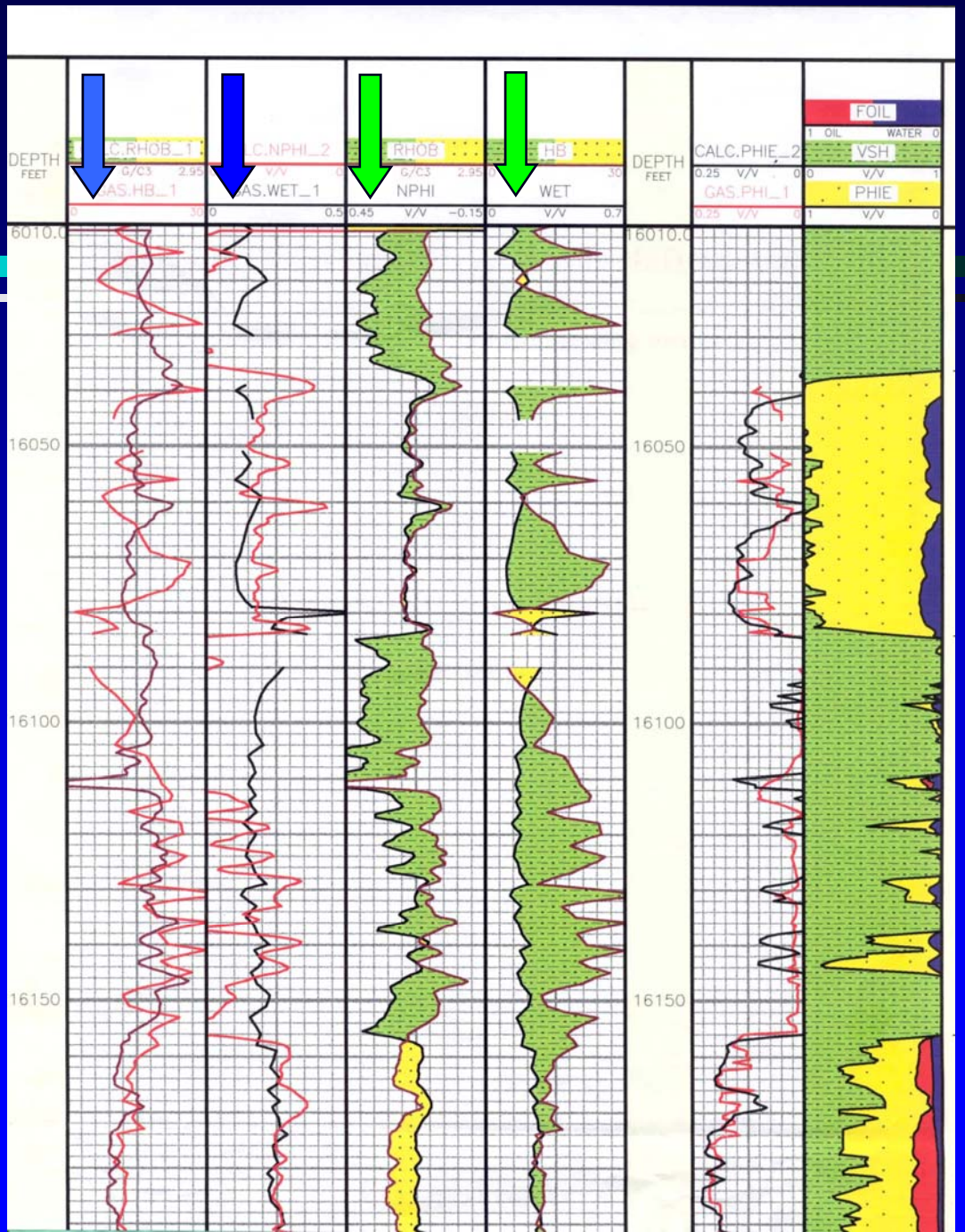
- Hydrocarbon Balance (HB)
- Density Log (RHOB)

Track 2: Comparison of Hydrocarbon Wetness with Neutron Porosity Log

- Hydrocarbon Wetness (Wet)
- Neutron Porosity Log (NPHI)

Tracks 3 & 4: Comparison of NPHI/RHOB Combination with Hydrocarbon Balance/Wetness Combination

- Green = Shaly
- Yellow = Sandy



Results IV

Track 1: Comparison of HB with Density Log

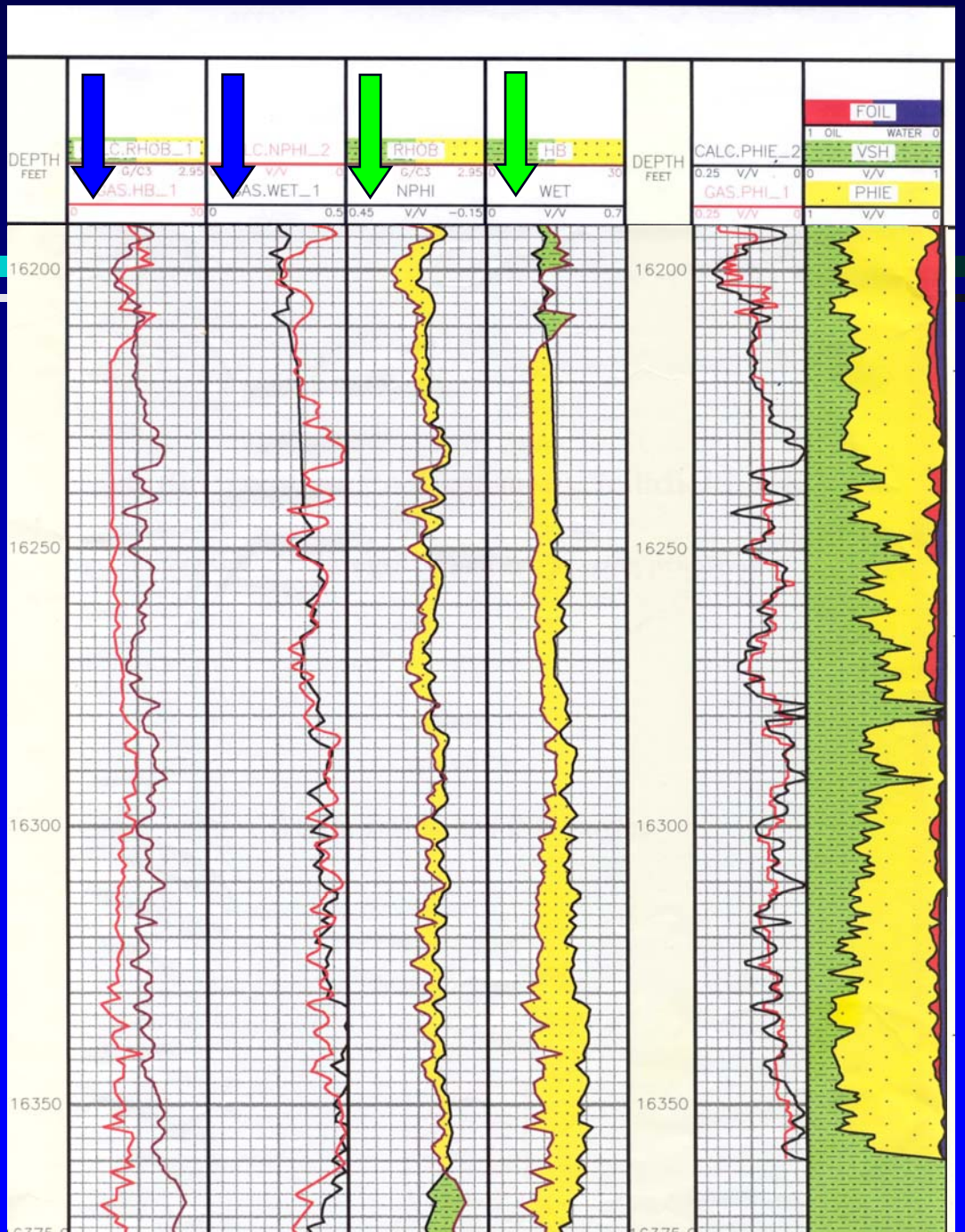
- Hydrocarbon Balance (HB)
- Density Log (RHOB)

Track 2: Comparison of Hydrocarbon Wetness with Neutron Porosity Log

- Hydrocarbon Wetness (Wet)
- Neutron Porosity Log (NPHI)

Tracks 3 & 4: Comparison of NPHI/RHOB Combination with Hydrocarbon Balance/Wetness Combination

- Green = Shaly
- Yellow = Sandy



Implications

- **Clearly, there is some relationship between:**
  - **The Gamma Ray Log and the Hydrocarbon Character Ratio**
  - **The Density Log and the Hydrocarbon Balance Ratio**
  - **The Neutron Porosity Log and the Wetness Ratio**
- **Genetic Algorithms can find this relationship, and use it to predict porosity**

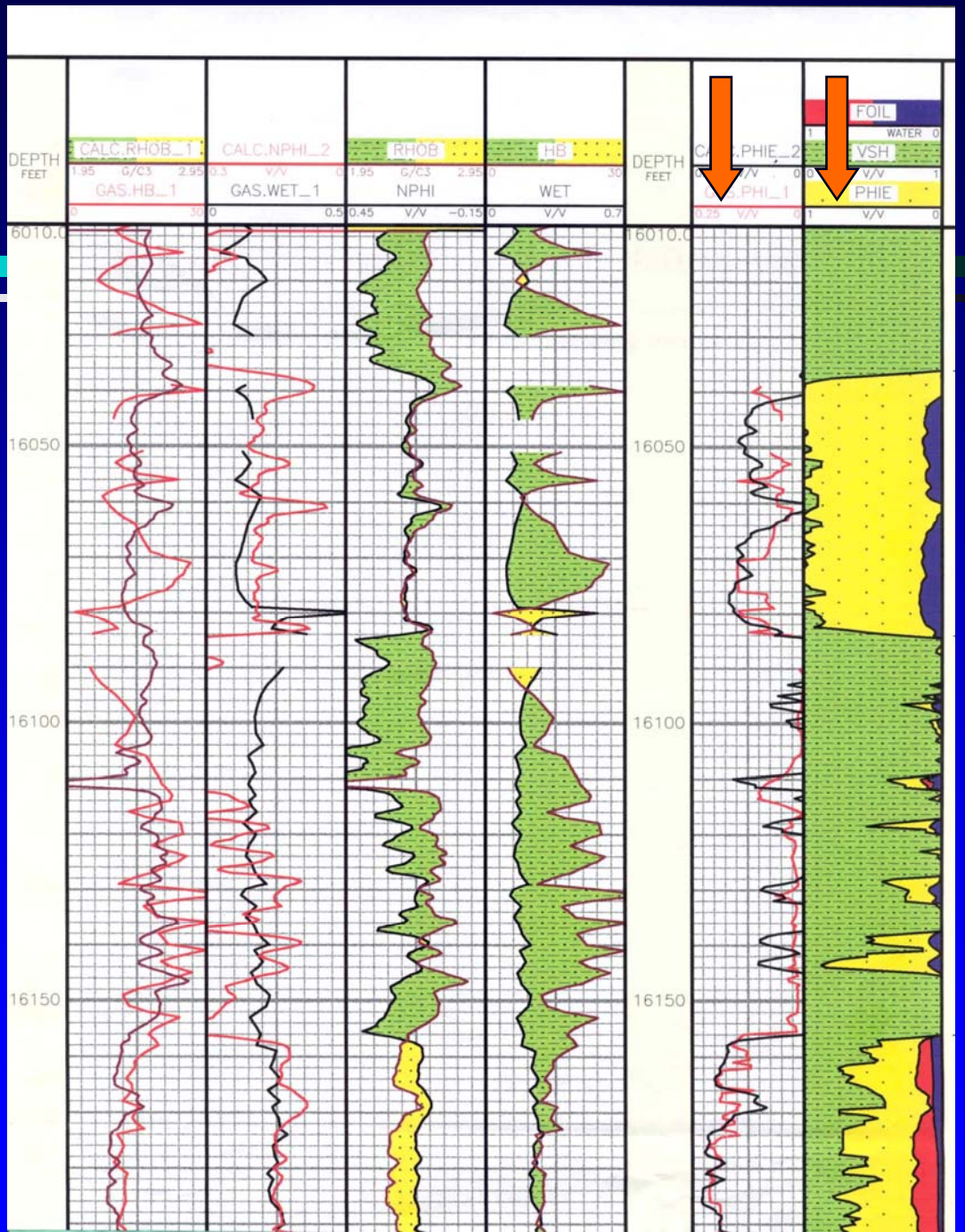
Results V

Track 5: Comparison of Porosity
- From Gas Ratios using GAs
- From Conventional Logs

The conventional logs are:
- Expensive
- Take many extra days to do

The gas log/GA method is:
- Free
- Available during drilling

Track 6: Final Rock Analysis from the Gas Ratio Data
- Shale
- Sand
- Oil
- Water



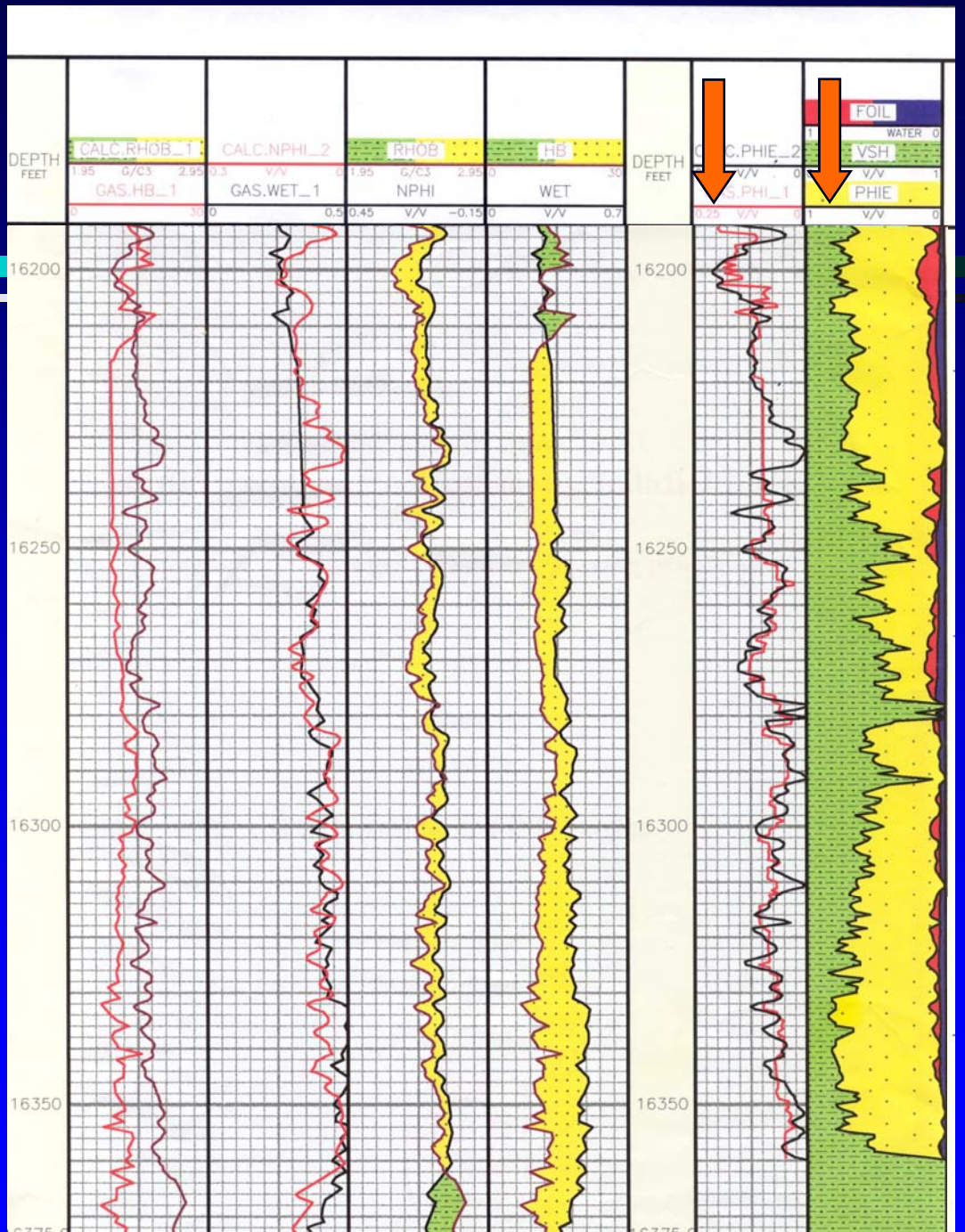
Results VI

Track 5: Comparison of Porosity
- From Gas Ratios using GAs
- From Conventional Logs

The conventional logs are:
- Expensive
- Take many extra days to do

The gas log/GA method is:
- Free
- Available during drilling

Track 6: Final Rock Analysis from the Gas Ratio Data
- Shale
- Sand
- Oil
- Water



Summary I

- Human development requires the energy and raw materials provided by oil
- The analysis of these reserves uses techniques that are expensive and can be damaging to the environment
- Improved analysis using gas cuttings measurements and GAs provide good porosity, permeability and lithofacies data
- Environmental damage is reduced by reducing the use of invasive exploration techniques and obviating the need for new wells and reservoirs
- However, oil production is optimised with less environmental impact