# Simplified and More Accurate Clay Typing Enhances the Value Added by Petrophysical Evaluation of Shale and Tight Gas Sand Plays*

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Search and Discovery Article #40487 (2010)
Posted February 19, 2010

*Adapted from oral presentation at AAPG Convention, Denver, Colorado, June 7-10, 2009

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## Abstract

This paper addresses the importance of correct and meaningful application of knowledge available from clay science research to the petrophysical formation evaluation of shales and shaly sand reservoirs to assess reservoir quality and compute fluid bulk volumes. It underscores the need to establish clay mineral types when performing petrophysical formation evaluation of shaly sand reservoirs. As shown, accuracy in clay typing is based primarily on using correct log response values for pure clay types such as smectite. This paper discusses modifications necessary to prevalent data on such log responses, based on previous clay characterization work. Simplified clay typing based on triple combo conventional logs is then possible using the rationalized values for nuclear logs. Using examples to validate these concepts, this paper highlights that clay mineral composition of a subsurface formation controls nuclear log responses - which are bulk measurements - regardless of mode of distribution of constituent clays and whether they are digenetic or depositional.

Most common models for shaly sand reservoirs correct for clay-bound water in shaly rocks, typically basing the "correction" on computed volume of clay or shale from logs, or from a laboratory-derived weight fraction of clay size particles in rocks (<4 microns). Now, considering that clay bound water (CBW) represents water of adsorption bound to the surface of a given clay mineral, the "correction" should be done only if the rock actually contains a clay mineral characterized by sufficient quantity of CBW to affect the logs that need correction! As noted, smectite is the only clay type characterized by any significant amount of CBW; clearly, knowing clay type is essential before selecting a formation evaluation model.

Implications of accurate clay typing for shale plays and tight gas sands is obvious in terms of achieving greater accuracy in predicting reservoir quality, calculating reserves, and reservoir modeling, thus helping reduce overall E&P risk.

# Simplified and More Accurate Clay Typing Enhances the Value Added by Petrophysical Evaluation of Shale- and Tight Gas Sand Plays

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Presented at the AAPG 2009 Convention
10 June 2009
Denver

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# Objectives for this presentation

- Well log based simple Xplot / overlay for accurate clay typing
  - Simple because it works with only basic triple combo
  - Accurate because it uses refined nuclear log parameters
  - NO LONGER  A SECRET
    - **Difference & Ratio of PhiD&PhiN sensitive to clay type**
  - Works for main clay types: smectite/illite/kaolinite/chlorite
- First discuss the petrophysical basis for the above
- Show examples

# GEOLOGISTS CAN BRING "colleagues" ON SAME PAGE

**THE TERM "CLAYS" SHOULD HAVE A "PREFIX"**

**e.g. ILLITIC CLAYS**

**ALL CLAYS ARE *NOT* SAME**

**ALL CLAYS DO NOT *SWELL***

**ALL CLAYS ARE NOT *SMECTITE/BENTONITE***

# STRONG FAITH AMONG SO MANY OF US

- ➔ Chart books are right!
  - Well, they are not
    - Live documents; follow Darwin's Law of Evolution.

# CHART BOOK : PREVALENT DATA ON CLAY TYPES

| | GR | RHOB | PHIN | PE |
|---|---|---|---|---|
| MONTMORILLONITE | 90.00 | 2.200 | 50.00 | 1.636 |
| ILLITE | 182.00 | 2.600 | 23.50 | 2.837 |
| KAOLINITE | 155.00 | 2.600 | 46.40 | 1.635 |
| CHLORITE | 50.00 | 3.300 | 50.00 | 9.973 |

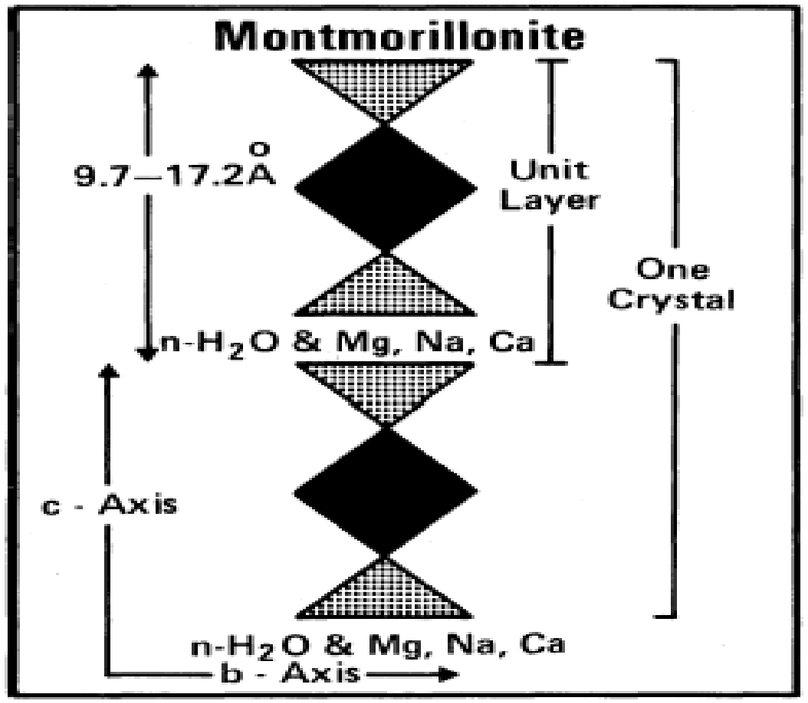
# Challenge ourselves and the “prevalent practices”!

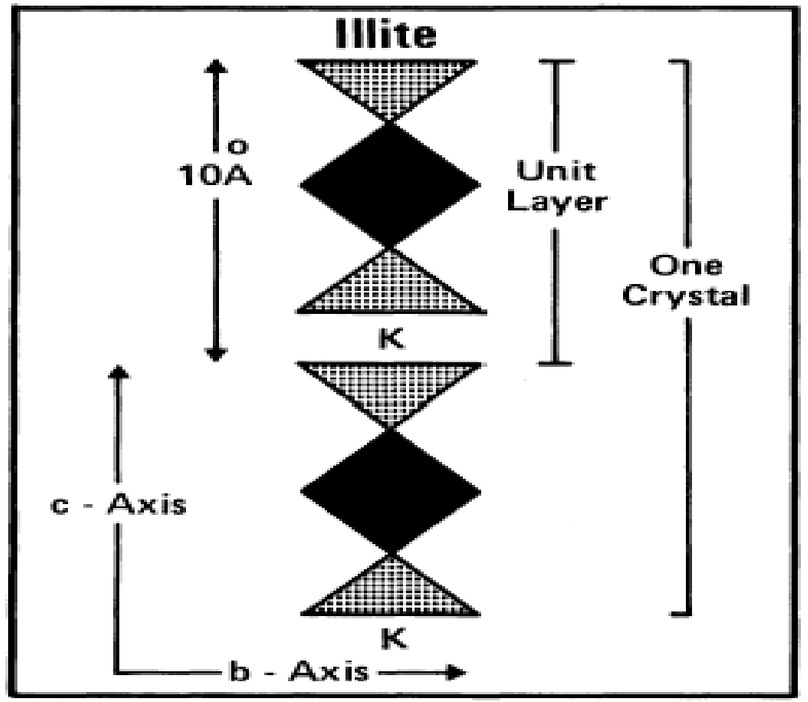
**→ Kaolinite and Chlorite radioactive?**

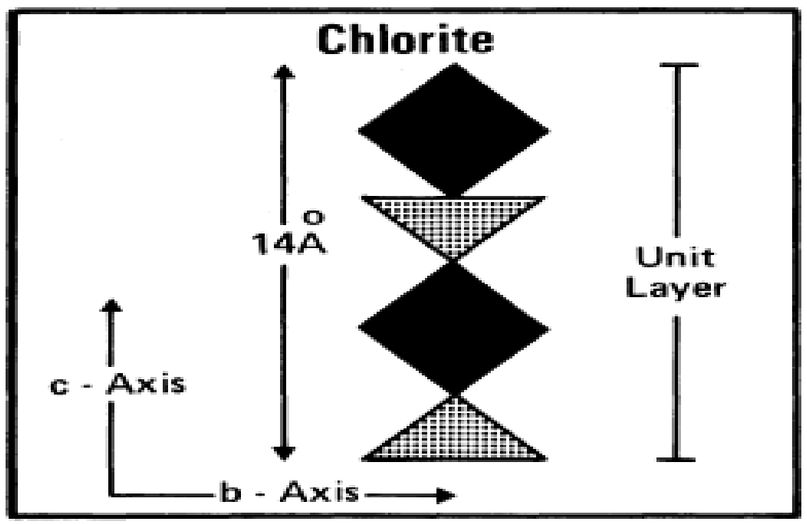
**→ Are the wet clay RHOB/PHIN params right?**

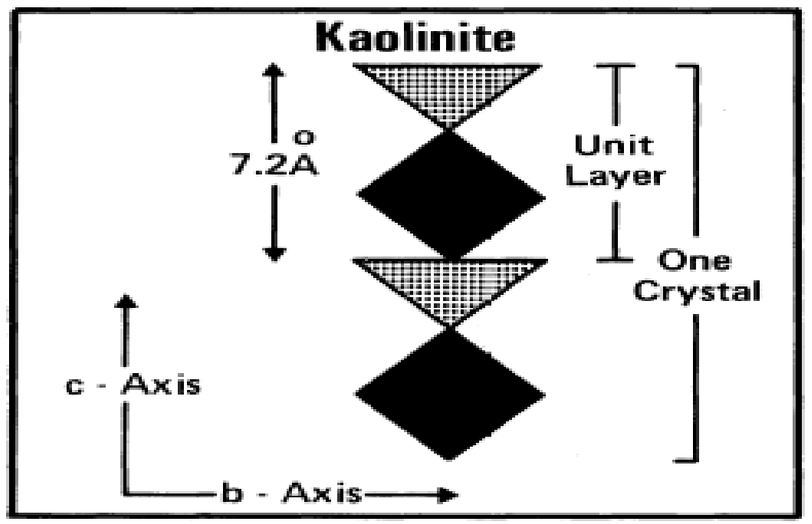
Answers can be obtained based on “clay science”

# UNDERSTAND THE CLAY WATER INTERFACE




c - Axis

**Schematic of Clay Crystal Structures**

**Clay : < 4 micron size fraction of rocks/soils that is composed of "hydrous layered alumino silicate minerals."**

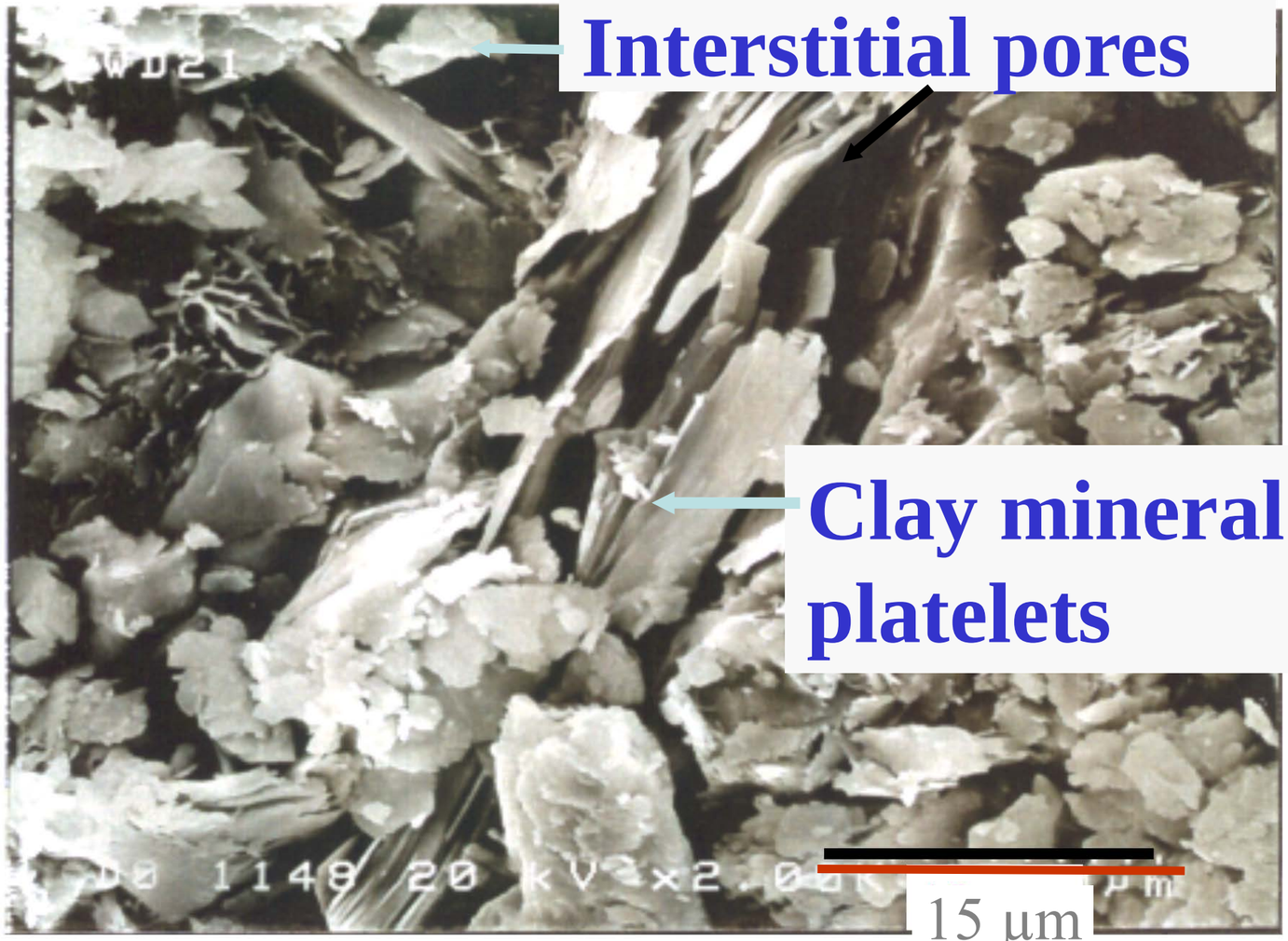
## Clay Bound Water:

➔ **An intrinsic property of a clay type**

- Adsorbed water on the clay surface (internal and external). It occurs as molecules hydrating the cations and as physio-sorbed molecules.

➔ **Excludes the volumetrically continuous phase in the interstitial pores; also excludes capillary bound**

# Pores and clay platelets



# Clay bound water content & surface areas of clay minerals

| | water | surface area (sq. m / g) | | |
|---|---|---|---|---|
| | (mg/g dry clay) | internal | external | total |
| **SMECTITES :** | **500-600** | **600-650** | **50-100** | **500-700** |
| **ILLITE/MICA:** | **50** | **50-100** | **50-100** | **50-100** |
| **CHLORITES:** | **10** | **20-40** | **20-40** | **10-30** |
| **KAOLINITES:** | **10** | **10-20** | **10-20** | **10-30** |

# Chitale et. al. have shown ....

- **Lab NMR indeed resolves the "*clay-bound water*". from the water in the discrete pores (yields Uni-modal $T_2$)**
- **Bi-modal $T_2$ spectrum when the clay-bound- and interstitial pore water coexist.**
- **Threshold amount of clay-bound water in the montmorillonite is about 500 mg/g of dry clay.**

# Application to the density and neutron logs

- Threshold value of 500 mg/dry g of clay can be used to modify wet clay density parameter

*assuming a range of 2.6 - 2.75 g/cc for the dry clay density of montmorillonite ....*

*The wet clay density centers around 1.7 g/cc*

*(currently used value is 2.2 g/cc)*

- That corresponds to a density porosity of 0.57 for a sandstone matrix
- Thermal neutron being a measure of total “H”

including hydroxyls : it should be 0.57 + 0.12 = 0.69

# REFINED PARAMETERS

| | SMECTITE | ILLITE | KAOLINITE | CHLORITE |
|---|---|---|---|---|
| Density DRY CLAY g/cc | 2.6 | 2.75 | 2.61 | 2.8 |
| Threshold quantity of water adsorbed : cc / dry gram of clay | 0.5 | 0.075 | 0.045 | 0.06 |
| Density WET CLAY g/cc | 1.7 | 2.5 | 2.43 | 2.64 |
| Thermal Neutron porosity (p.u.) | 0.7 | 0.25 | 0.58 | 0.68 |
| Density porosity (sandstone matrix) | 0.58 | 0.09 | 0.13 | 0.06 |
| Density porosity (limestone matrix) | 0.59 | 0.12 | 0.16 | 0.04 |

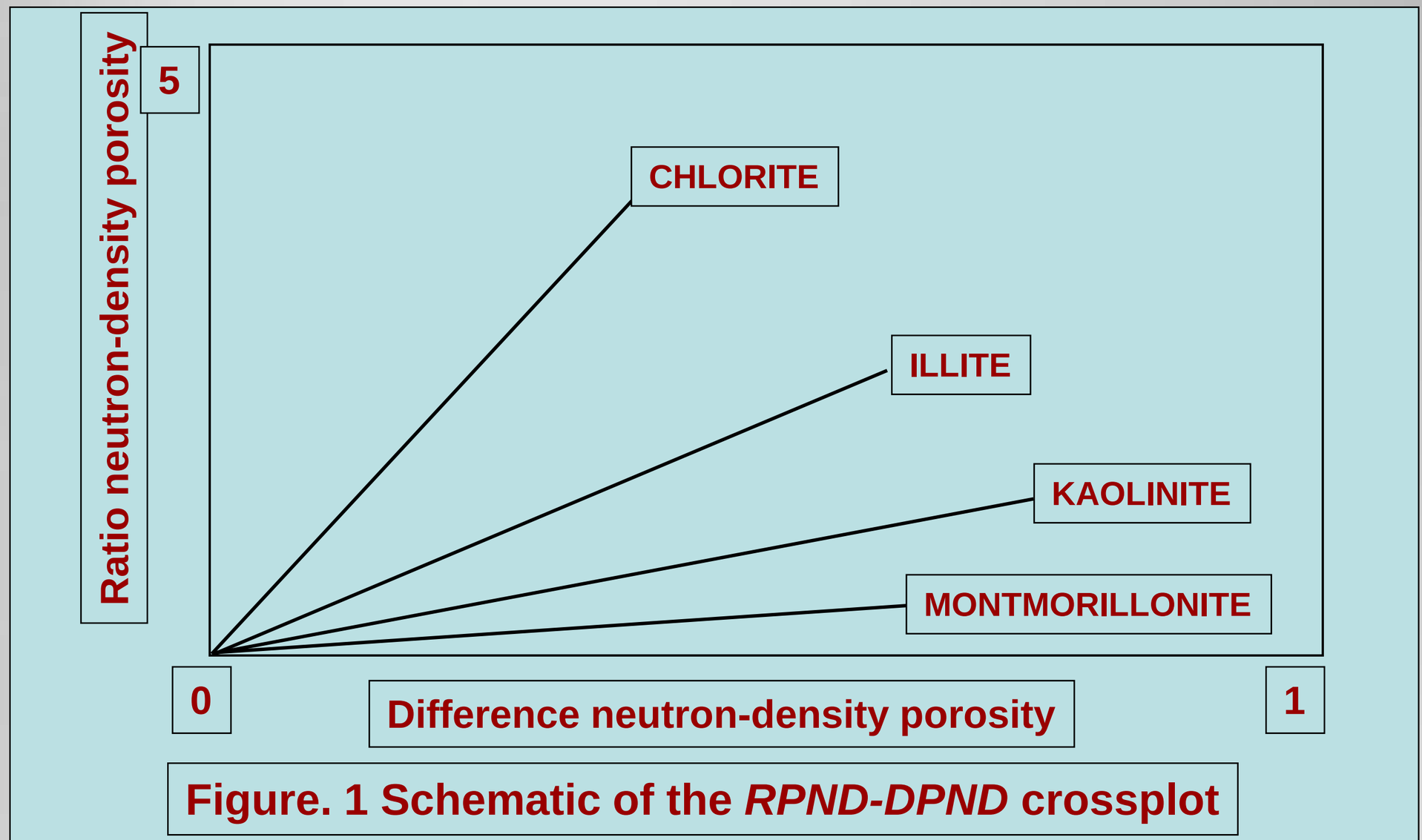



**Figure. 1 Schematic of the *RPND-DPND* crossplot**

# PARAMETERIZATION OF THE XPLOT

DPND = [Vclay * ( PHINwc - PHIDwc)]

RPND = [Phie + (Vclay * PHINwc)] / [Phie + (Vclay * PHIDwc)]

CBW index = [RPND - 1] / DPND

Characteristic of a clay type

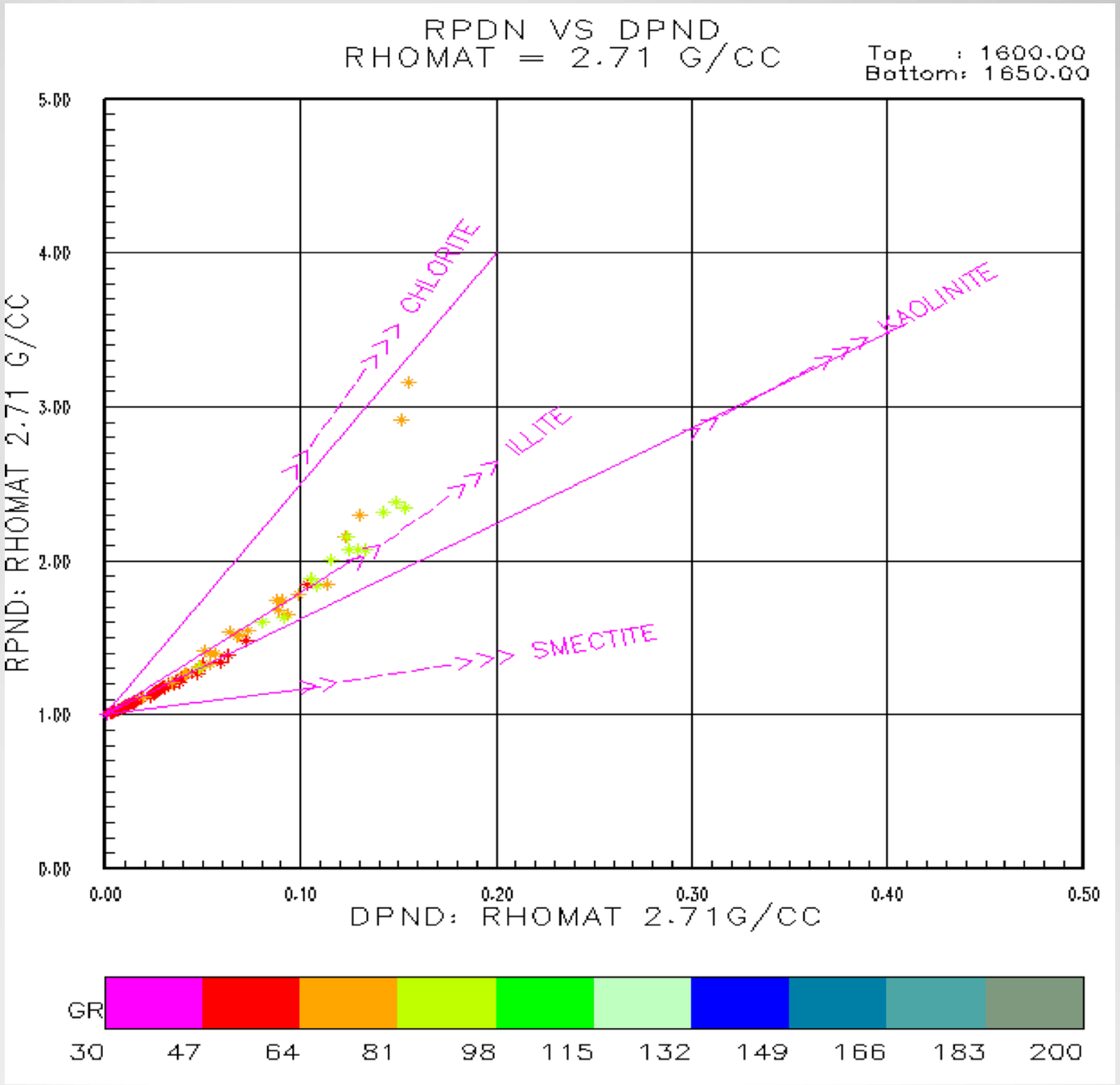

RPDN VS DPND
RHOMAT = 2.71 G/CC
Top : 1600.00
Bottom: 1650.00
RPND: RHOMAT 2.71 G/CC
DPND: RHOMAT 2.71G/CC
5.00
4.00
3.00
2.00
1.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
CHLORITE
ILLITE
KAOLINITE
SMECTITE
GR
30
47
64
81
98
115
132
149
166
183
200

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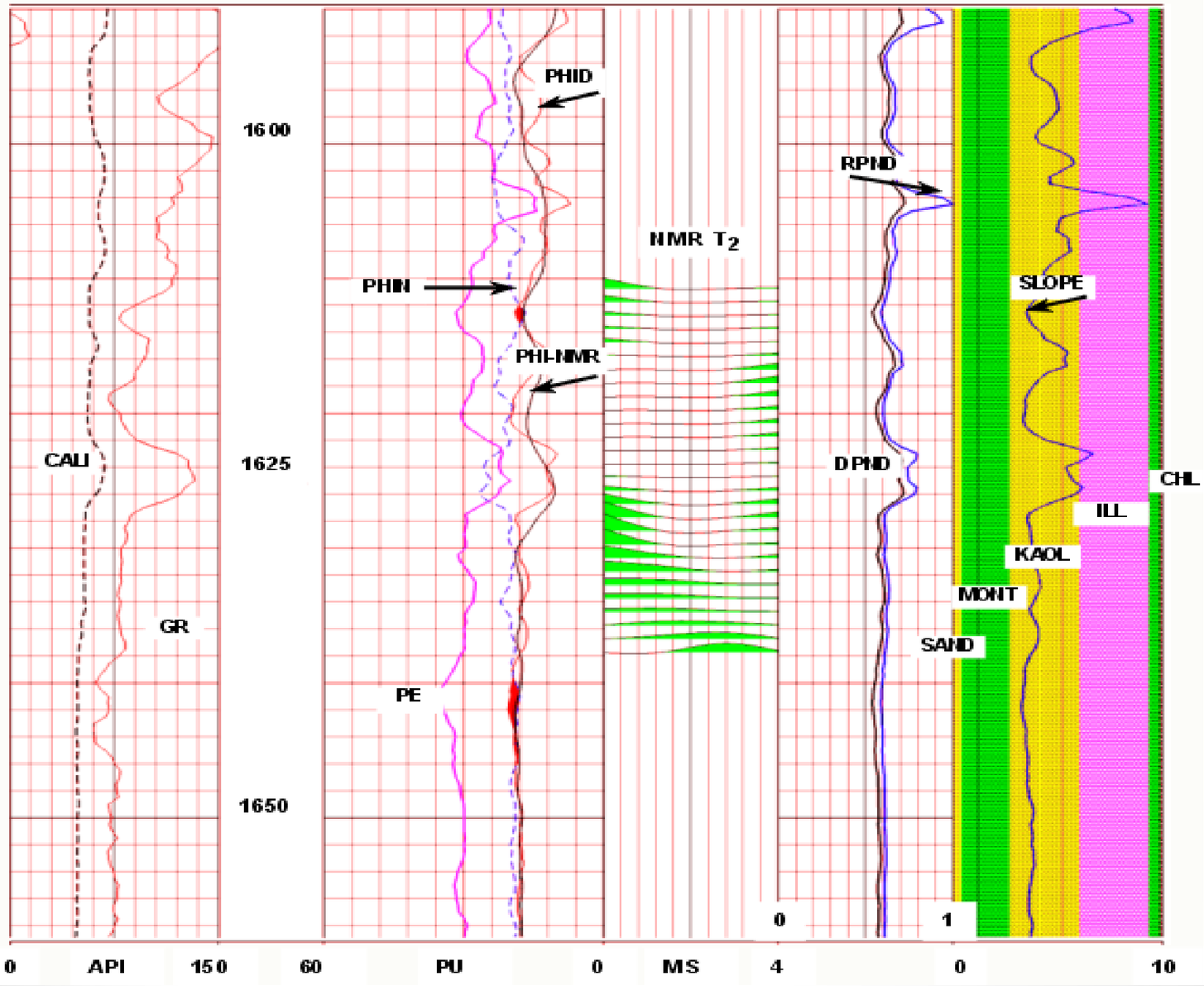
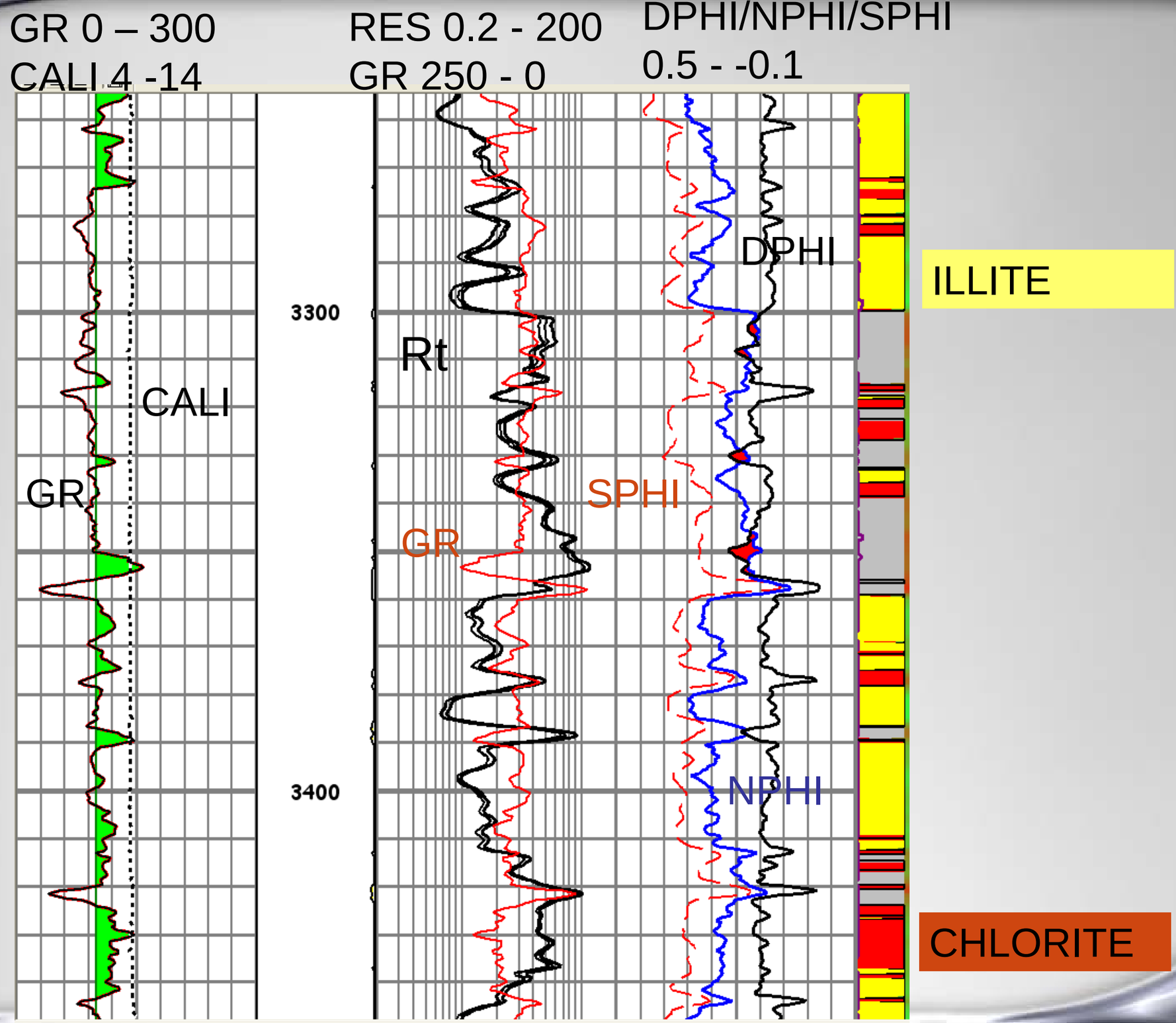
Figure 3: Quick look clay typing answer product: an overlay of various logs



US
MIDCON

EXAMPLE



## Summary and Conclusions

- New and simple Xplot / overlay proposed
  - Important to use newly refined parameters
  - Technique works for main clays: smectite/illite/kaolinite/ chlorite
- Accuracy in clay typing NEEDED for unconventional reservoirs where mineralogical modeling is the key to determining Sw. Also the rock properties (brittleness) are linked to clay type.

# Exchange of ideas, questions & answers

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