Title: Dealing with Unique Minerology in Petrophysics Logs

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**Abstract:** XXXXX

**One-Sentence Summary:** This paper aims to discuss the petrophysical considerations that need to be made for unique mineralogy that is sometimes seen in logs, like tuffs and volcanics, oplaines, CO2 and helium

Introduction

Most petrophysical models are built with an understanding that the most oil and gas deposits are found in basins that have an underlying mineral system that is sedimentary in nature. These sedimentary basins are primarily composed of minerals that are either silicates (), such as quartz, feldspars, micas and other clays, or carbonate ( (chalk, dolomite, limestone), and while the nature of the petrophysical properties and reservoir type are very much dependent on the environment of deposition and can vary across sedimentary basins (homogeneous, heterogeneous, tight, layered or laminated), our main petrophysical equations are designed to deal with these select basket of minerals. However, we know from both individual as well as collective industrial experience that there are instances where unique minerals are encountered in fields drilled around the world.

In Indonesia [1] and Australia [2], for instance, pyritic sandstones are encountered in some hydrocarbon bearing reservoirs. These have some interesting effects on the logs, from having high densities to low resistivity responses. Kennedy and Clavier et al both discussed the impact of pyrite (FeS2) on modern logs [1, 2] and noted that while pyrite has a variety of effects on resistivity and nuclear tools, such that measured values can be drastically different from those typically encountered

In the Gulf of Mexico (GOM) [5], in fields offshore Brazil [6] and Egypt [7], evaporite salts (halite, anhydrite, and sylvite) layers can overlie depositional basins or be present within producing reservoirs. While salt acts as an excellent sealing facies, due to its non-net nature with its very low porosity and permeability, salt encountered in reservoir sands has a deleterious effect on logs; resistivities can be very high (due to a lack of accessible pore space), density is well constrained since minerals are pure, with either very high or low values dependent on the elements present, and neutron can be either very high or very low dependent again on the nature of the salt type [8].

Some minerals encountered in hydrocarbon bearing reservoirs result in missed pay opportunities (low resistivity/ low contrast pay) and/or can appear as non-net sands if higher potassium (K), thorium (Th), or uranium (U) contents are not properly accounted for (hot sands). The Northern Carnarvon Basin in Australia, for example, contains reservoir sands in the Mungaroo Formation which are glauconitic in nature [9]. Glauconite is an iron rich clay variety, and is ductile and compacts under overburden conditions, potentially occluding primary porosity. Properly accounting for glauconite in a reservoir firstly requires an understand of the microporous nature of the glauconite particle itself. Hot sands are present in the Tenggol Arch, offshore east Peninsular Malaysia and are characterized by higher gamma ray (GR) signature associated with Th. This needs to be accounted for, otherwise the evaluation of clay proportions would be incorrect, resulting in an underestimation of net sand. The accounting of the hot sand components also allows for the proper correlation across wells at the field scale [10].

In all the above examples, literature adequately describes how such reservoirs should be dealt with. In almost all cases, the fundamental petrophysical equations derived for volume of shale (VSH), porosity (f) and saturation (Sw) will apply, so long as appropriate corrections/ calibrations are used. There are exceptions to the rule, however. If salt, for example, is encountered in a continuous zone but deposited as its own layer, then petrophysicists may choose to either treat the zone as non-net and not interpret or else, adopt a simplistic, but consistent method, given that there are no set standard industry equations. In this case, the interpretation goal is not to determine salt properties, but rather to allow for comparison across large areas with salt bearing intervals, and to avoid interpreter bias. A simplistic method could be VSH from GR, total porosity from nuclear magnetic resonance (if available), density or sonic (but with consistent end points) and Sw set to 1. If there is salt present as pore filling material, then adopting an interpretation method as described by Saxena and McDonald is perhaps the way to go [11].

Aside from unique minerologies, reservoirs can also sometimes intersect formations where the primary fluid is CO2, H2 or He. In terms of their logging characteristics, they appear almost like hydrocarbon bearing reseroivrs, albeit with some nuanced differences.

In this paper, we will discuss, via several case studies, some of the experiences and interpretation methods in dealing with unique situations observed in our work and how they are quantified for petrophysical applications. We will discuss wells that have intersected (a) volcanoclastics (tuffs and ash), (b) opalines, and wells where the pore fluid is primarily (c) CO2 or (d) helium. We will explain how we have addressed such petrophysical challenges, and discuss which tools are perhaps the most reliable in discriminating potential mineral signature.

Case Study 1: Volcaniclastic Reservoirs

Background

Tuffaceous reservoirs are known to contain hydrocarbons which can sometimes be of significant volumes, examples being in China and South America. However, such reservoirs are relatively underexplored and underproduced, fundamentally because they are challenging to understand. Typically, if tuff facies are encountered in conventional reservoirs, they are ignored. Yet, a proper understanding of how such reservoirs behave may prove appealing to explorers looking for the next big “whale” in exploration.

The flow mechanism in such reservoirs is governed by numerous variables; the very nature of the tuffaceous facies means that pore structure, pore type/ size, mineralogy, and rock-fluid interactions impact reserves estimation, recovery factor and sweep efficiency at the reservoir scale. Pore scale distribution of fluids within the rock will, in turn, determine petrophysical and geophysical response of the reservoir rock. Conventional logging methods may not necessarily work well in tuffs as they contain trace amounts of radioactive minerals, and grains sometimes contain surface roughness at the nanoscopic scale that impacts how fluids are distributed.

Case Study Parameters

We will discuss 2 wells from 2 different oil producing fields. Well #1 in Field A was drilled in the Gulf of Mexico (GOM) and had ash and volcanic beds present within an intersected Tortonian formation. This well was logged with modern “conventional” petrophysical logs, with a full log suite of GR, density-neutron (D-N) and resistivity (RES). Well #2 in Field B was drilled in South America and had been logged with older “Russian style” logs, with uncompensated GR, N and RES.

Petrophysical Approach:

The main challenge with the interpretation of any tuff facies is the lack of a universally-accepted interpretation methodology, because of variability in the logs and fields. Indeed, it becomes necessary to design a “fit-for-purpose” method, guided by the question as to what benefit delineating the tuff facies would bring, as well as the type of data with which you have to work with. For Well #1, the goal is to correlate the volcaniclastics across wells to determine field wide correlatability.

Results and Discussion

Case Study 2: Opalines

Background

Petrophysical Approach:

Results and Discussion

Case Study 3: CO2 for Sales Gas

Background:

Petrophysical Approach:

Results and Discussion

Case Study 4: Exploring for Helium

Background:

Petrophysical Approach:

Results and Discussion

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***Discussion and Implications:***

***AAA****:*

***BBB:***

***CCC:***

***DDD:***

***EEE:***

**Limitations of Study and Conclusions:**

# **References**

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