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Research paper

The Radioactive Sands & Low-Resistivity Low-Contrast Pays Reservoir in Deta Field, Niger Termit Basin

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Abstract

Radioactive and low-resistivity pay sands are often petrophysically underestimated under conventional exploration approaches. Deta Field is a good example of hydrocarbon producing field with low resistivity contrast and radioactive sands. Deta field located in the South-West flank of Dinga Trough, Termit Basin. Hydrocarbon had been discovered and produced from Alter Sokor formation, E0-E5 sand zones. Radioactive sands found in Deta field reservoir formations are due to clay minerals in sandstone composition. Types of clay minerals in radioactive sands are studied from E0 and E1 formations after the crossplot analysis using Spectral Gamma Ray (SGR) log, photoelectric log, and density-neutron log crossplot. High percentage of illite are found as types of clay minerals in radioactive sand. The low resistivity pays identified in the main hydrocarbon producing reservoir sand zones are due to the dispersed clay minerals. The oil-producing reservoir sandstone recorded with relatively low resistivity curve of 15 - 20 ohm·m only. The difference of resistivity curve between reservoir intervals and adjacent shale formation is less than 7 ohm·m. This study aims to understand the clay content in radioactive sands and relate to low resistivity pays reservoir. This research finds that both reservoir problems of radioactive sands & low resistivity pays are indirectly related.

Keywords: *radioactive high GR sand; low resistivity low contrast (LRLC) pays; highly conductive; petrophysical underestimation; clay minerals; geological facies*

1. Introduction

Deta field is a clastic hydrocarbon producing reservoir located in the SW flank of Dinga Tough in Termit Basin, SE region of Niger. Deta field is a rift basin with hydrocarbon accumulated within reservoirs in the graben. Radioactive sandstone reservoir is suspected in Deta field. Besides, the hydrocarbon bearing reservoir intervals are identified with low- resistivity low-contrast (LRLC) in resistivity log response. This paper will present the radioactive sandstone and LRLC pay reservoir in Deta field and further explain on the analysis results.

Radioactive Sand

Sand are normally characterized with low radioactive content and result in low Gamma Ray (GR) log value. What is radioactive sand? Radioactive sand is suspected as sediments sourced from nearby granitic highlands which have not undergone sufficient weathering transportation [1]. The radioactive sandstone contains parent minerals like zircon, highly arkosic (high feldspar content), micas, glauconite or uranium-rich water. The highly radioactive parent minerals give high GR log response and are often mistaken as shales in interpretation. Deta field is believed to have potential radioactive reservoir sand verified with the source of sediments studied. It is found that Termit Basin sediments are sourced from the nearby Aïr Mountain located in northern Niger, within the Sahara Desert. The Precambrian to Cenozoic Aïr Mountains consist of alkaline granite intrusions which appear dark in colour. The distance between Aïr Mountain and Termit Basin is about 380 kilometres (Figure 1). Therefore, there is a possibility of Eastern Niger basins, e.g. Termit Basin containing radioactive sands from the mountain considering the distance. There are several types of radioactive sand depending on combination and percentage of the parent minerals. In sandstone, the thorium value is related to clay content; high potassium concentration is due to the abundance of mica and potassium feldspars [1].

Figure 1 The location map of Aïr Mountain.

Low-Resistivity Low-Contrast (LRLC) Pays

LRLC pay is reservoir that produces water-free hydrocarbon, but the resistivity log response of the reservoir interval is low, indicating high water saturation [2]. Low-resistivity pay can be referred as resistivity range of 0.5-5 ohm-m in deep resistivity logs or low contrast in resistivity logs characteristic between pay zone and adjacent shale-bed or water zone [3]. Low-resistivity pay occurs usually in fresh water reservoir as the resistivity log readings between pay zone and water zone do not show high contrast [4].

The studies of rock conductivity suggest two types of conduction: a) Electrolytic conductivity and b) Electronic conductivity [3]. Clean sandstone usually has high resistivity particularly reservoir sand that contains hydrocarbon. The main reason for low resistivity phenomenon is the presence of conductive minerals in clean reservoir sandstone. If sandstone, in some cases is highly clayey, and contains heavy mineral, i.e. pyrite, the resistivity log response will become low. [5] High clay content bound the sandstone matrix causing irreducible water and low resistivity response. The interbedded shale and dispersed shale within the reservoir give low resistivity response. [6]

Problem Statement

There are two major problems faced in reservoir characterization of Deta field: radioactive sediments from nearby granitic Aïr Mountain and LRLC hydrocarbon reservoir.

Radioactive sands that response like shale in GR log impacted on picking the correct reservoir sand intervals for net pay calculation. The overestimation in calculation of shale volume, Vsh which solely depends on GR log should be reviewed in this research study.

Low-resistivity hydrocarbon reservoir is another problem that leads to petrophysical underestimation of hydrocarbon reserves found in reservoir. The low resistivity might have been overlooked during the log interpretation, resulting in inaccurate water saturatin, Sw and porosity which highly depends on resistivity log. [7]

The Aim of Research

This paper conducted research to identify the radioactive sandstone and low-resistivity low- contrast (LRLC) pay intervals in Deta Field. The aim is to find the solution for both problems and solve petrophysical underestimation of pay thus reserves.

2. Materials and Methods

2.1 Radioactive Sand

Can be categorized into different types by analyzing the Th/K ratio. Under lack of data, indirect solutions are sought to solve the radioactive sand problems. Data available based on the needed for radioactive sand reservoir analysis:

- Spectral Gamma Ray (SGR) log
- Photoelectric (PEF) Cross Section log
- Density – Neutron log

Firstly, the suspected radioactive sandstone is highlighted in zones as shown in Figure 2 in the results section. In this study, S1 and S2 intervals are selected for further analysis. There are two solutions that will be discussed here:

I. Crossplot of SGR logs and Photoelectric Cross Section data

Thorium Vs Potassium (Th/K) concentration crossplot is used to study the presence of radioactive sand. The K concentration will be higher if the sandstone formation is rich with clay content. The Th/K crossplot in Figure 3(a) is plotted for the wells involved and includes only potential radioactive zones. Next PEF log against Th/K ratio crossplot in Figure 3(b) are used to find out the clay minerals in radioactive sand.

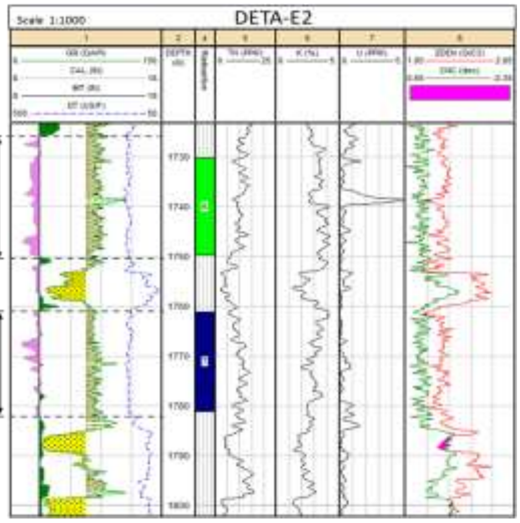


Figure 2: S1 & S2 zones are highlighted as sample of potential radioactive sand due to the mud cake condition but high GR value in Deta-E2. Sonic log (DT), NGS logs (Thorium-Th, Potassium-K, Uranium-U) and density neutron log are shown for reference.

II. Crossplot of sonic density (ZDEN) log and neutron density (CNC) log

ZDEN Vs CNC crossplot is to study the difference in the density of radioactive sand and non-radioactive sand. The crossplot in Figure 4(a) & (b) includes only density data from potential radioactive sand zones & non-radioactive sand zones.

2.2 Low-Resistivity Low-Contrast (LRLC) Pays

Data available for LRLC pay analysis:

- Resistivity log (wash zone, transition zone, and deep zone) for resistivity comparison
- Side Wall Core (SWC) descriptions for reference to lithology
- Pressure data for fluid type prediction
- Sonic density and Neutron density logs for determination of hydrocarbon
- Gamma Ray (GR) log for basic sand/shale differentiation

Core samples or thin section images would be very beneficial in determining shale minerals distribution in sandstone that cause apparent low resistivity, but it is unavailable in the data set. There are limited only two core samples with petrographic images (Figure 5) of the same E2 sand zone, taken from well Keta-2 in a nearby field for reference.

Total of three sand groups, A, B, and C, in Deta-E2 are highlighted to be discussed. All the three sand groups are rich in hydrocarbon as proven from the Drill Stem Test (DST) results, extracted and recorded in detail as shown in Table 1.

Table 1 : The hydrocarbon reservoir details in Deta-E2.

Details	Deta-E2 (2075m TVDss)
Volume of HC produced	10.0L fluid/8mins
HC Ratio	Film of oil, 100% water/mud filtrate
Fluorescence Response	Milky yellow
Colour | Density of HC	Light Brown| 1.01 g/cm^3 (filtrate/oil)
Pressure Plot	0.35psi/ft. (Oil)
Deep Resistivity (R_D)	0.18 ohm/m

3. Results and Discussion

3.1 Radioactive Sand

The results of radioactive sand analysis through well data crossplot as the indirect solutions is as shown in the following.

I. Crossplot of NGS logs and PEF log data

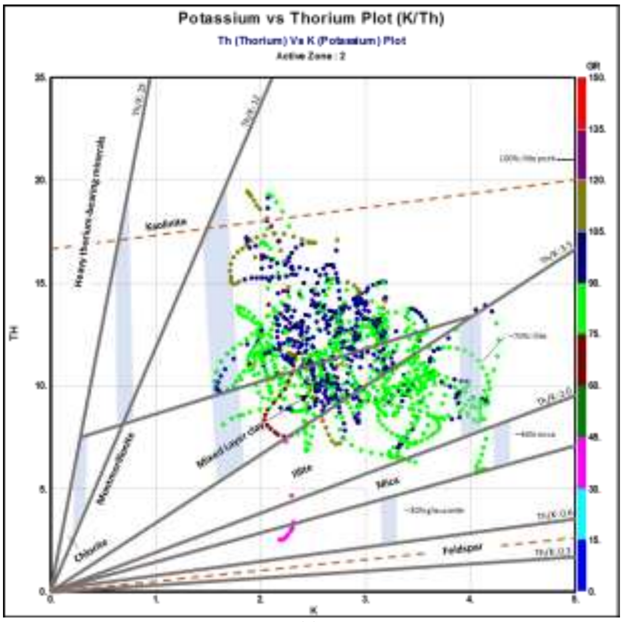
Nearly half of the radioactive sand Th/K data points fall in the range of mixed-layered clay and Illite in Figure 3(a); lots of data accumulated near and inside the bounded mineral region of Illite in Figure 3 (b). Illite is known as the altered product of muscovite and feldspar from weathering processes and hydrothermal alteration. The results proves abundance of clay in the radioactive sandstone interval which might be the reason for high GR value similar to the adjacent shale.

II. Crossplot of ZDEN and CNC log

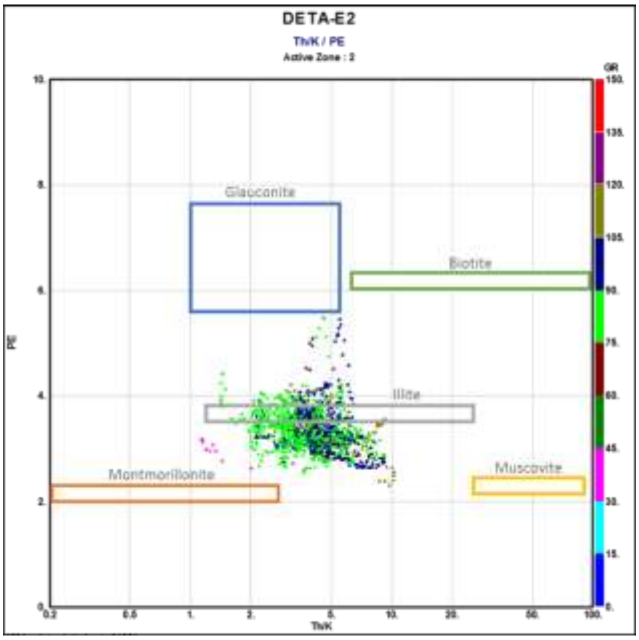
Apparently, density of the rock matrix of radioactive sand in the crossplot would be higher due to presence of denser minerals. As compared to the non-radioactive sand, the crossplot data shows much less dense sandstone as seen in Figure 4(a). The water-bearing clean non-radioactive sandstone are selected from those within the depth range where radioactive sand is found. This proven that heavy minerals and clay minerals accounts for the higher density of the radioactive sand.

3.2 Low-Resistivity Low-Contrast (LRLC) Pays

The recorded deep resistivity is typically lower than usual hydrocarbon-bearing sandstone shown in other fields. In comparison, the deep resistivity at the hydrocarbon-bearing sandstone and the adjacent shale formation, the differences in resistivity response is less than 7ohm-m. This means the resistivity logs shows the sandstone is still highly conductive although it contains hydrocarbon. The SWC descriptions (7th track of Figure 5) from the sand zones shows abundance of kaolinite cement. From the radioactive sand studies, clay mineral i.e. illite with parent rocks of kaolinite are identified in the sand zones. The cation-exchange capacity (CEC) of illite is smaller than that of smectite but higher than that of kaolinite, typically around 20 – 30 meq/100 g [8]. Although the core samples data of Deta field is not given, the two petrographic images in Figure 6, taken from the core of E2 sands are used to help in the understanding of shale distribution. The dispersed clay minerals or mud as shown in Figure 6 had filled up the pores between large quartz grains. The higher wettability of clay minerals increases water saturation of the sandstone formation and leads to apparent low contrast as well as low resistivity between sandstone and shale formations.

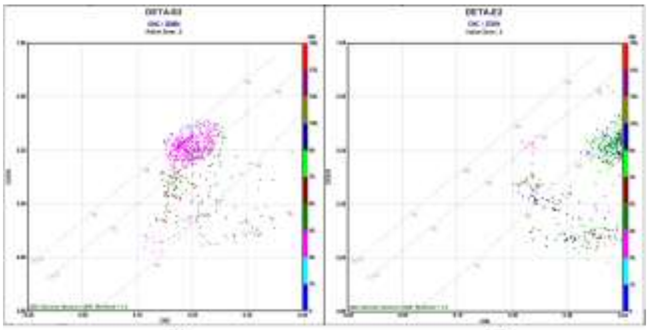


(a)



(b)

Figure 1: (a) The Th (ppm) vs K (%) crossplot for the potential radioactive sand zones in Deta-E2 labelled with mineral identification reference lines from Natural Gamma Ray Spectrometry (NGS) Log by Schlumberger. (b) The PEF log (B/E) vs Th/K**.**



(a) (b)

Figure 2: The conventional sonic density vs neutron density crossplot for: (a) water-bearing non-radioactive sandstone (0-70 API) in Deta-E2; (b) potential radioactive zones in Deta-E2.

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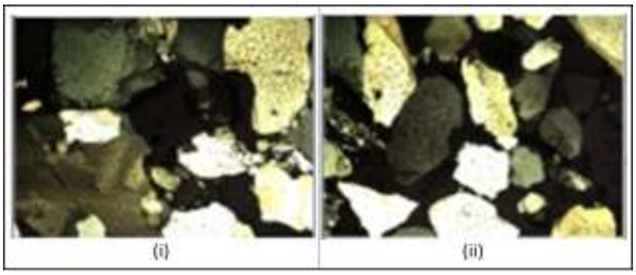

(i) (ii)

Figure 5: Petrographic images of Keta-2 well from nearby field. (i) Conglomerate of unsorted size and sub-angular grains and mud filled up pore space. Mainly quartz, and gneissic fragments; clay and diagenetic calcite filled up the pores. (ii) Coarse grains sandstone, occasionally conglomeratic in parts. Mainly quartz, and gneissic fragments; clay and diagenetic calcite filled up pore space

4. Conclusion

This research results in fresh insights on the types of radioactive sandstone phenomenon in Deta field hydrocarbon-bearing reservoirs. The high clay content in radioactive sandstone is analysed as illite from the clay minerals studies. This result matches with the SWC descriptions on the abundance of kaolinite, parental minerals for illite in the respective sandstone intervals. The clay content is believed to be the reason contributing to low resistivity pays accounting for irreducible water due to dispersed shale in the sandstone formation. This explains why the resistivity shows low contrast response between hydrocarbon-bearing sandstone and adjacent shale formation. In conclusion the hypothesis of this study on clay content in radioactive sand is a controlling factor to the LRLC reservoir problem is true.

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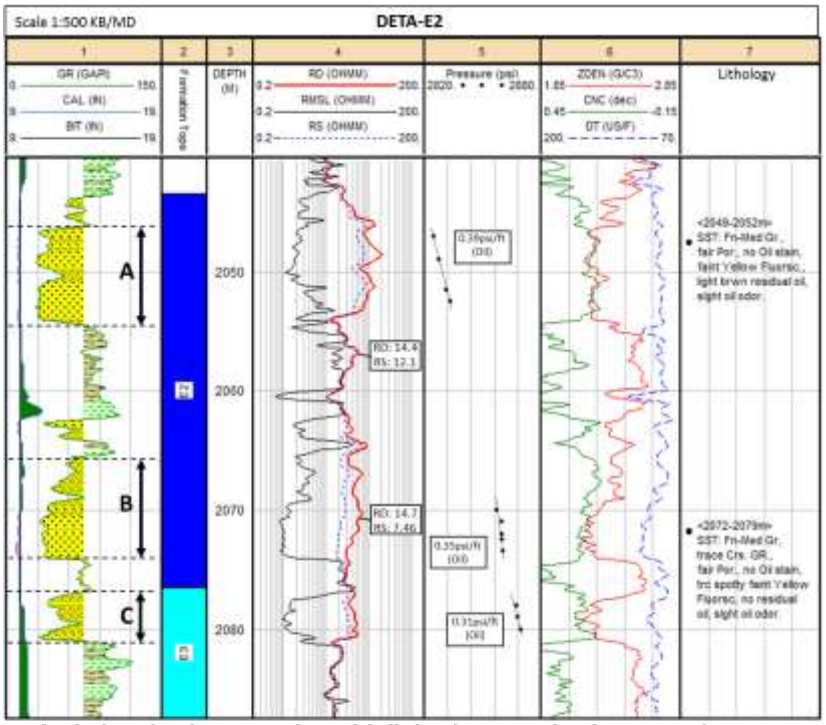

Figure 3 Deta-E2 well A, B, and C hydrocarbon bearing sandstone labelled and interpreted with resistivity logs, pressure data, density logs and SWC lithologic descriptions**.**