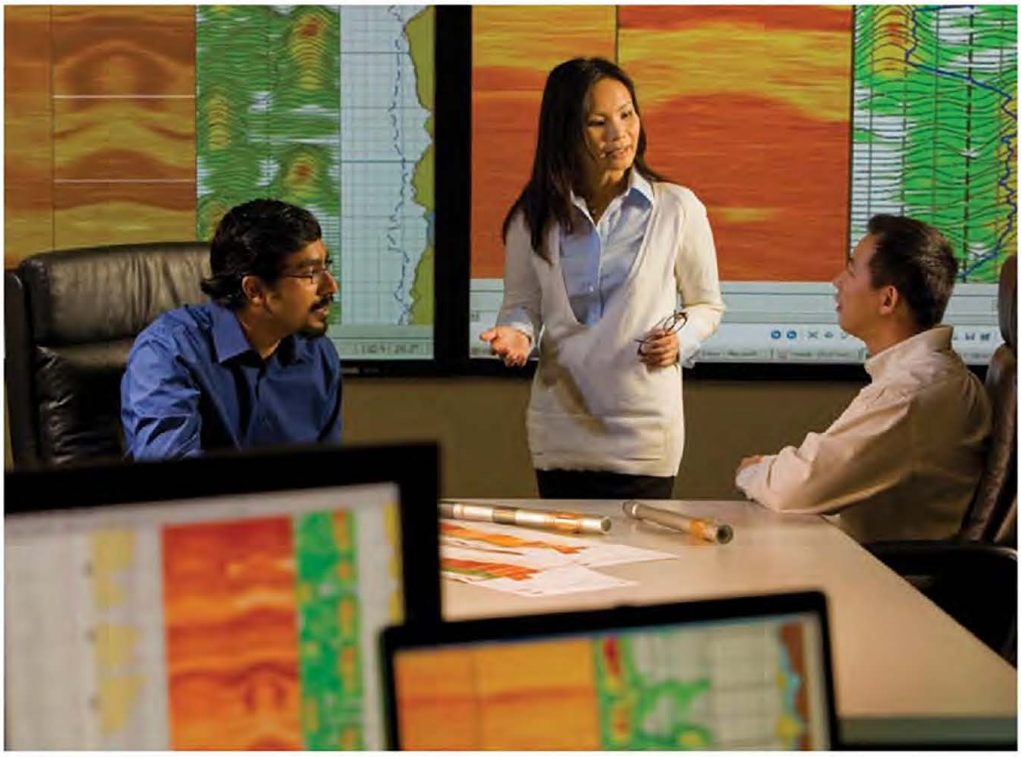
RPM Pulsed Neutron Data analysis
Sigma Monitoring in ROSSUM-WEERSELO Field



Company: NAM BV

Field/Asset: ROSSUM WEERSELO

Well: ROW-4: 3rd Acquisition – September 2023
ROW-5 – ROW-7A: 2nd Acquisition, September 2023

Prepared by: 5.1.2.e & 5.1.2.e

Date: Nov 22th, 2023

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Objectives

A new logging campaign with Reservoir Performance Monitor (RPM) pulsed neutron was run in 2023 to check for integrity of salt bodies after another water injection operation, as per routine monitoring (or time-lapse) salt dissolution assessment.

This acquisition corresponds to:

- 3rd operation on well ROW-4 after 2021 and 2022. The latter was initiated because of the observed anomaly in the 2021 survey.
- 2nd Operations on wells ROW-5 and ROW-7A previously logged only in 2021.

The scope of work was, once again, to check for differences in main formation, borehole and fluids by analyzing all relevant curves from pulsed neutron capture mode acquisition (PNC), specifically looking for any changes in Halite salt rocks conditions. In the period between this acquisition and the previous acquisition only a limited amount (typically 60 m^3) of fresh water was used to flush the wells, in order to ensure accessibility to the target interval. The Schoonebeek oil field is not producing since January 2022, hence there has not been any water disposal into these wells.

This report refers to main findings from Sigma analysis of this repeated survey. For ROW-4, the results are compared to the interpretation of the data sets acquired in June and January 2022. For ROW-5 and ROW-7A these are compared to the single previous acquisition from June (ROW-5) and November (ROW-7A) 2021.

Well History

Rossum Weerselo is one of the three Gas fields (Tubbergen, Tubbergen-Mander, Rossum-Weerselo) situated in East Netherlands. Located to the south of Tubbergen, this reservoir produced gas from Zechstein Carbonatic sequence but it was converted into injection of low-saline production water from the Schoonebeek oil field where steam has been injected until its temporary closure in 2021. Since the injection started in early 2011, close attention is being given to the integrity of Cap Rock, represented by anhydrite and halite layers. This survey is targetted to ensure the halite is not suffering from salt dissolution caused by this water.

Fig 1: Rossum-Weerselo Field Map

Executive Summary

Following initial logging operations in June 2021, followed by a second acquisition in January 2022 a third logging operation was performed in ROW-4 with the Baker Hughes RPM pulsed neutron tool. The objective is to re-evaluate the condition of the ZEZ4H, ZEZ3H, ZEZ2H halite intervals and assess for changes. At the same time, a second logging operation was run in ROW-5 and Row-7A wells.
Key findings from this campaign, well by well, were:

Data Evaluation

ROW-4

- Prior the logging operation 30m^3 fresh hot water was pumped in hole to ensure access to the logging interval.
- A summary of the 2023 acquisition findings indicates:
  - In ZEZ2H halite interval, the log responses appear to show no increase of Salt Dissolution and cavity size. The thickness of the brine-filled interval behind casing in ROW-4 is unvaried compared to 2022 log data (1364.5-1361.5m).
  - Current SGFC measurement indicates that the liquid in the salt cavity has changed from salt water (2022) to fresh water (2023) as consequence of the hot (fresh) water flush before the logging campaign (to ensure access to the well). The porosity index (RPOR) also drops because of the freshwater presence in the cavity.
  - Similar effects in Sigma and RPOR are also visible in front of Anhydrites layer below, in particular @ 1365.6 down to 1366.4m. RPOR is now very low and proof that something has changed to fresh fluid presence. This indicates a potential void behind casing (in cement and/or matrix).
  - Evaluation of potential salt dissolution over ZEZ4H and top of ZEZ3H halite block is not possible from 1262 to-1241m because log responses are affected by gas presence in the borehole.
  - Rest of data are overlaying with previous acquisition.
- In summary, there appears to be no change in SALT layer integrity compared to 2022 acquisition; with the exception that salt water behind casing has been replaced with fresh water.

ROW-5

- Fresh water was injected prior to logging to ensure access to the logging interval.
- Well ROW-5 was logged in 2023 for the 2nd time: RPM data repeat with 2021 data.
- No evidence of changes in the Halite layers.
- High radiation levels which can include Oxygen Activation from water flow, previously seen, is reconfirmed in 2023,

ROW-7A

- Well ROW-7A was logged in 2023 for the 2nd time: RPM data repeats with 2021 data.
- Fresh water was injected prior to logging to ensure access to the logging interval.
- No evidence of changes in the Halite layers.
- The wellbore fluids were different between the 2021 acquisition and the new 2023 measurements. In 2021 the Fluid Capacitance indicator (FCAP) was very low because of Gas in the wellbore above 1290m. The 2023 borehole is water filled up to 1170m the Gas-Water-Contact in the wellbore was seen to be rising from Pass 1 to Pass 3.

Conclusions

- The 2023 data acquisition did not show any changes with respect to the earlier data, with exception of fluid replacement in ROW-4 in the potential cavity or void space previously flagged in 2021/2022 reports. This is interpreted as a change from salt water to fresh water behind casing
  - A similar response was observed in the anhydrite at 1366m. This suggests the presence of a void behind casing
- Overall all Halite rocks in ROW-4 appear to be unchanged from previous acquisition in 2022.
- Similarly ROW-5 and ROW-7A appear unchanged compared to 2021 acquisition.

Recommendations

- If water injection in wells ROW-5 and ROW-7 is resumed, the previous recommendations still hold. These are contained in the 2021 and 2022 reports.

Selected Wells, Logging Program, and Intervals

RPM Dual detector Pulsed Neutron Capture mode data (PNC2D) were acquired in ROW-4, ROW-5 and ROW-7A with following logged intervals at specific average log speed:

ROW-4 (27 September 2023):

- 1205.33 – 1409.09 m (Main pass) @ 16-18 ft/min
- 1208.53 – 1407.94 m (Control Pass) @ 16-18 ft/min
- 1208.9 – 1403.07 m (Repeat Pass) @ 18 ft/min

ROW-5 (28 September 2023)

- 1143.68-1355.29 (Main Pass) @ 16-18 ft/min
- 1144.5 -1355.06 (2nd Pass) @ 16-18 ft/min
- 1143.53-1353.99 (Repeat pass) @ 16-18 ft/min

ROW-7A (29 September 2023)

- 1148.02-1411.07m (Main Pass) @ 18 ft/min
- 1147.26-1411.14m (Repeat Pass) @ 18ft/min
- 1146,6-1410.1m (Additional Pass) @ 18 ft/min

The tool utilized for logging was once again, the Reservoir Performance Monitor (RPM), in exact same configuration as previous acquisitions in 2021 and 2022.
Well completion in ROW-4 consists of a production 3"1/2 tubing in a 7" casing above a long-perforated interval across the Zechstein Carbonate gas reservoir.
Well completion in ROW-5 consists in a 7" casing with a selective 4" completion set above lower perforation from 1250 to 1258m while the main tubing section starts above upper perforations, from 1152m to surface.
Well completion in ROW-7A in the interval of interest consists in a 9"5/8 casing with 3.5" tubing from 1220m to surface.

Well Schematics following in this report will highlight configurations during logging operations.

Interpretation Approach

See Interpretation approach section in 2021 Report

Observations

In line with the 2021 report, the following plots summarize all main curve responses. Expanded section in figure 2b highlights the increase of thickness visible from porosity change to fluid response. The curve visualization refers to Main Pass 2 only. Comparisons of all Passes (either 2021 and/or 2022 and/or 2023 both) are available on separate composite plots.

ROW-4 Composite Plot: comparison of 2021-2022-2023 measurements

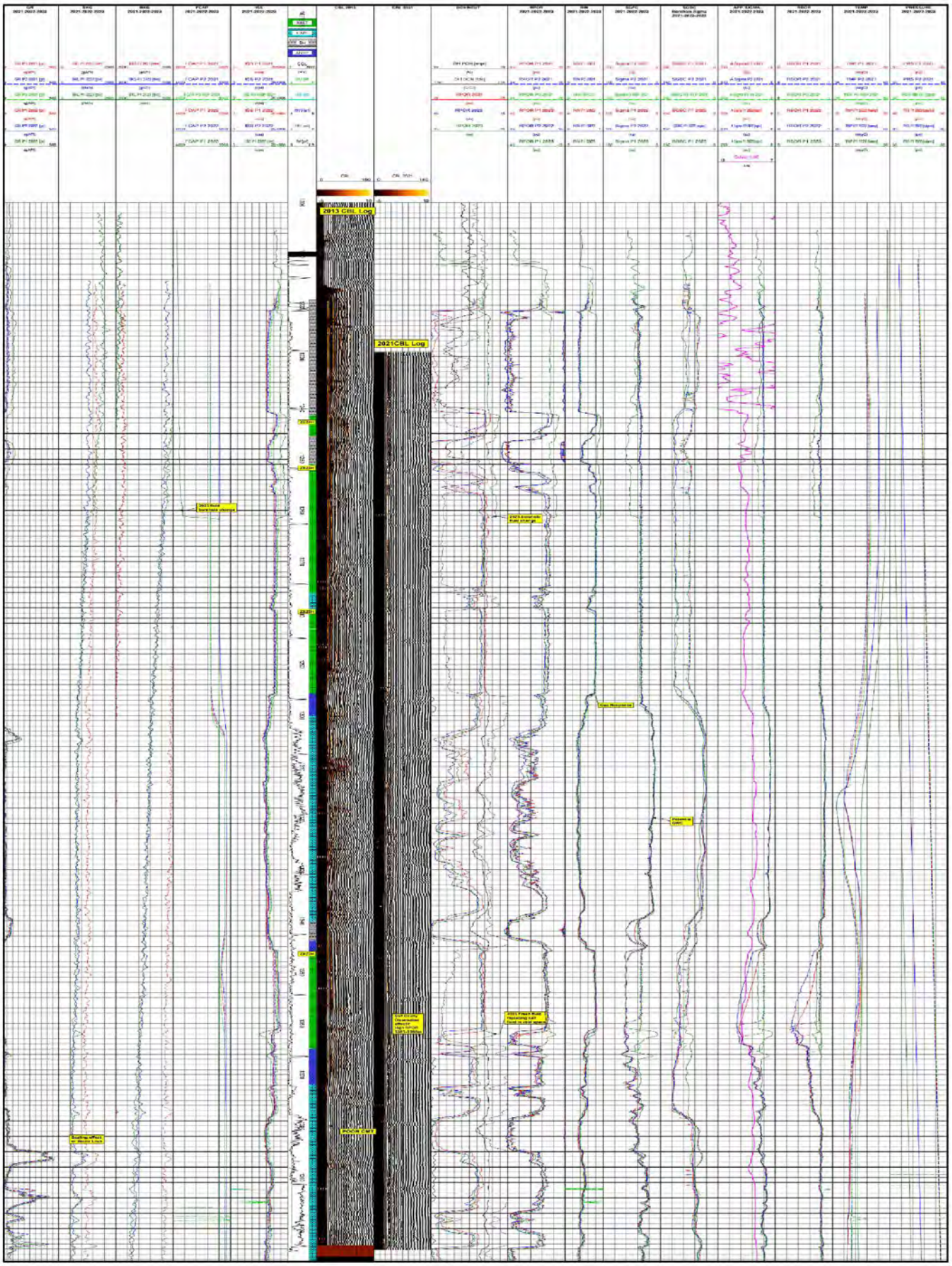

Figure 2: ROW-4 composite comparison 2021-2022-2023 data

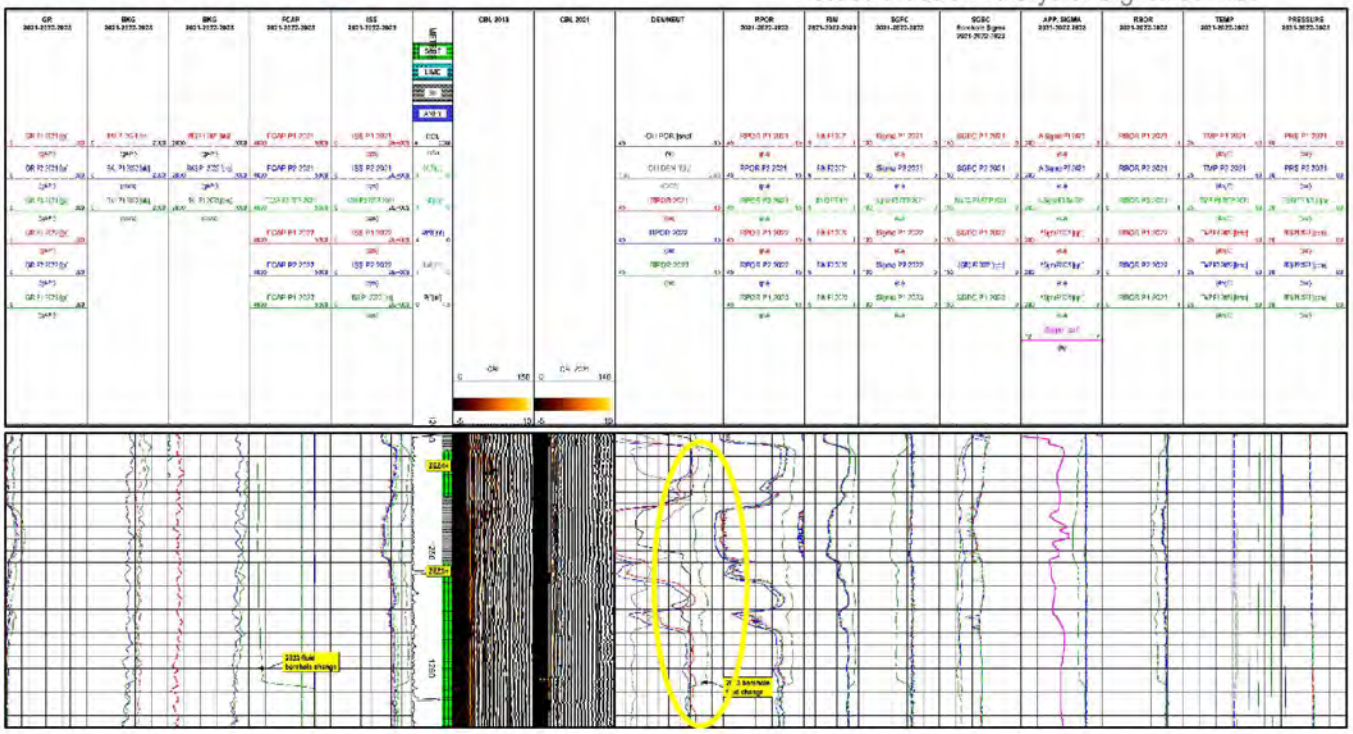

Figure 2a: ROW-4 Pulsed neutron log composite including borehole caliper and cement log and indicating the change in response, due to the possible gas presence in the borehole

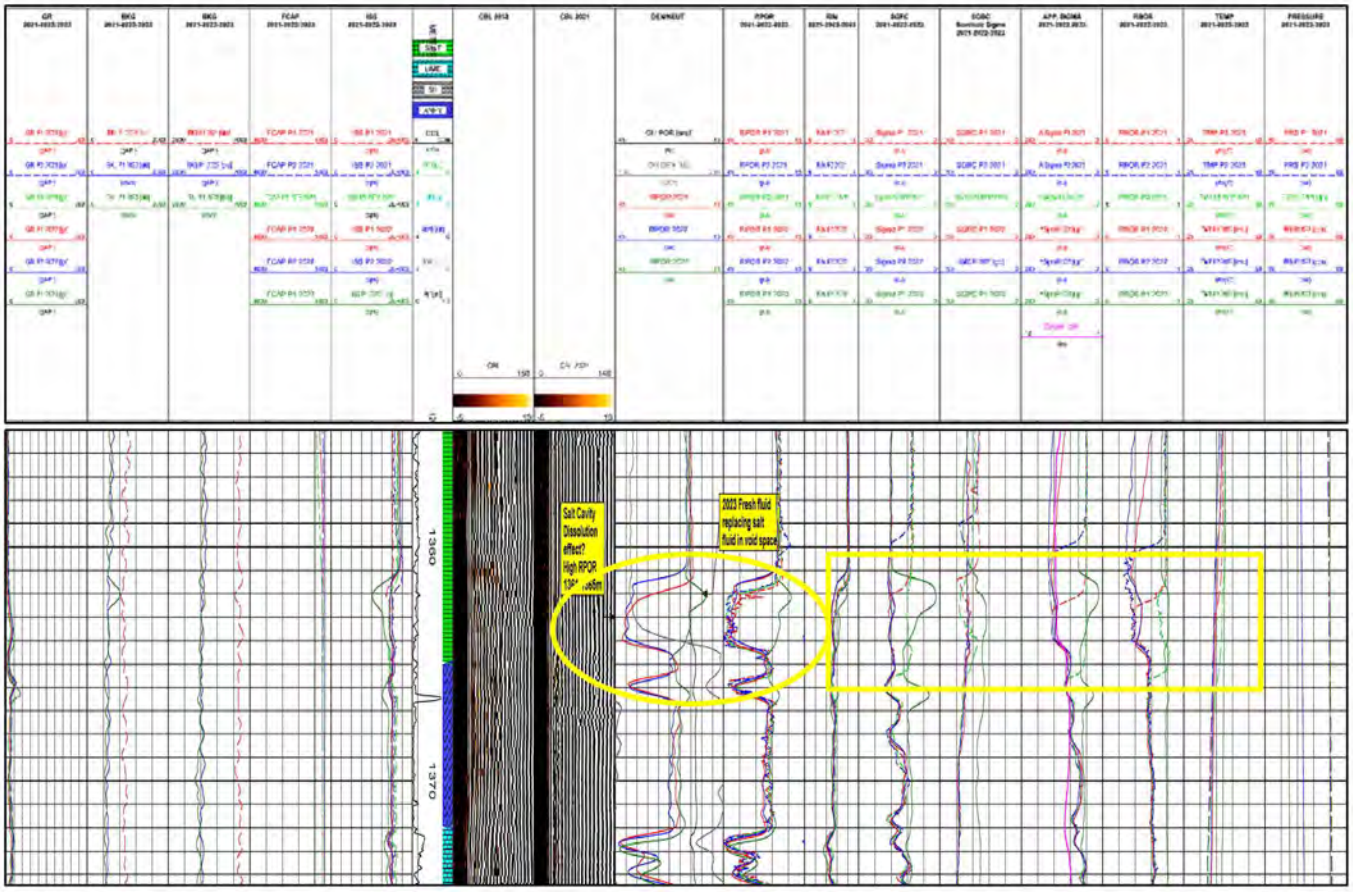

Figure 2b: Expanded section in base of Halite ZEZ2H to highlight the changes in Apparent Sigma, RPM porosity (1360-1365.5m). Yellow Circle focuses on the unchanged void thickness visible from 2021 application, while Yellow Rectangle indicated the change of salinity range along the SALT ZEZ2H meaning fresh water from injection operation.

ROW-5 Composite Plot: comparison of 2021-2023 measurements

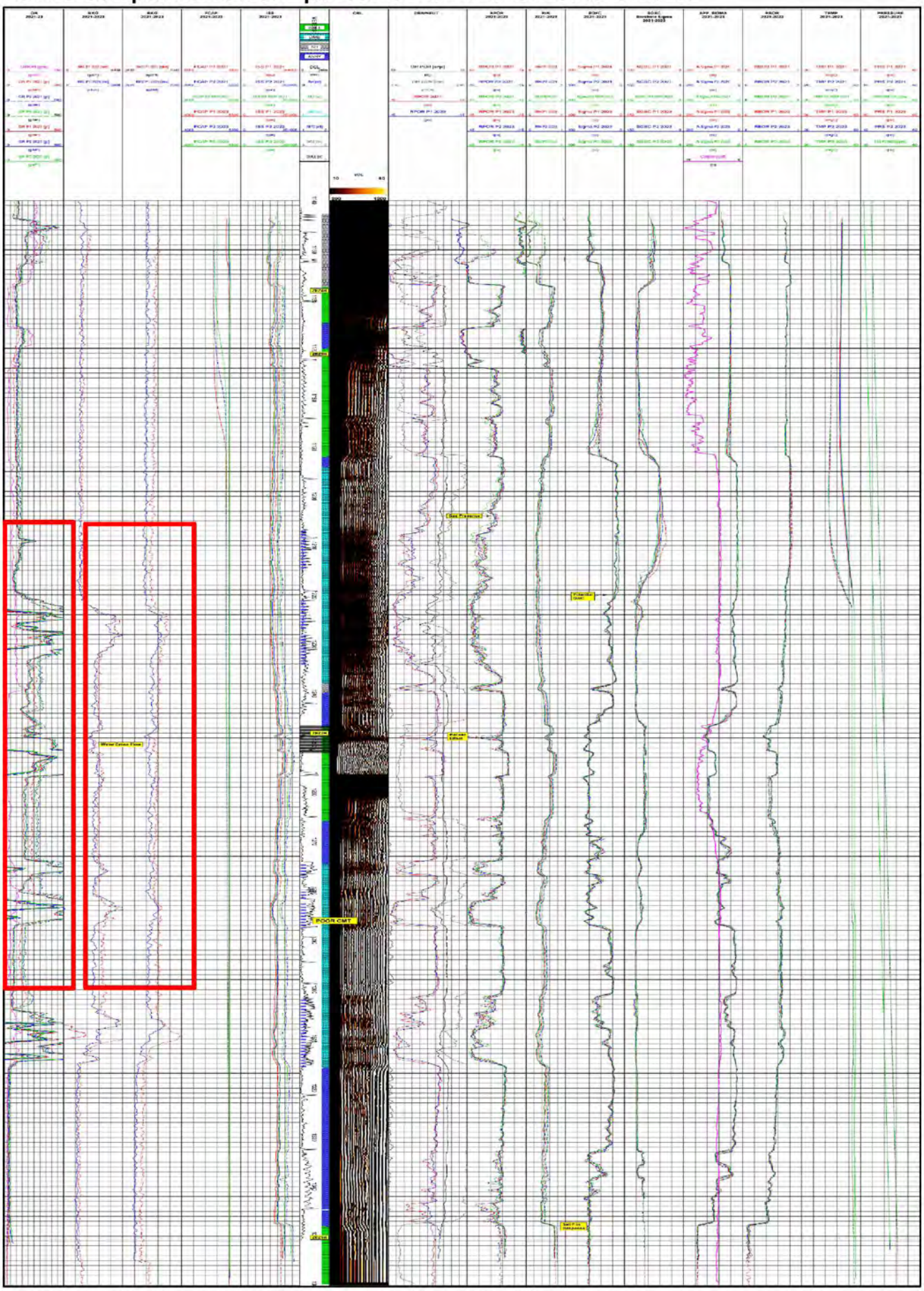

Figure 3: Row-5 composite comparison of 2021 and 2023 data. The Oxygen activation indicators in the red rectangles highlight the potential water flow between the upper and lower perforations.

ROW-7A Composite Plot: comparison of 2021-2023 measurements

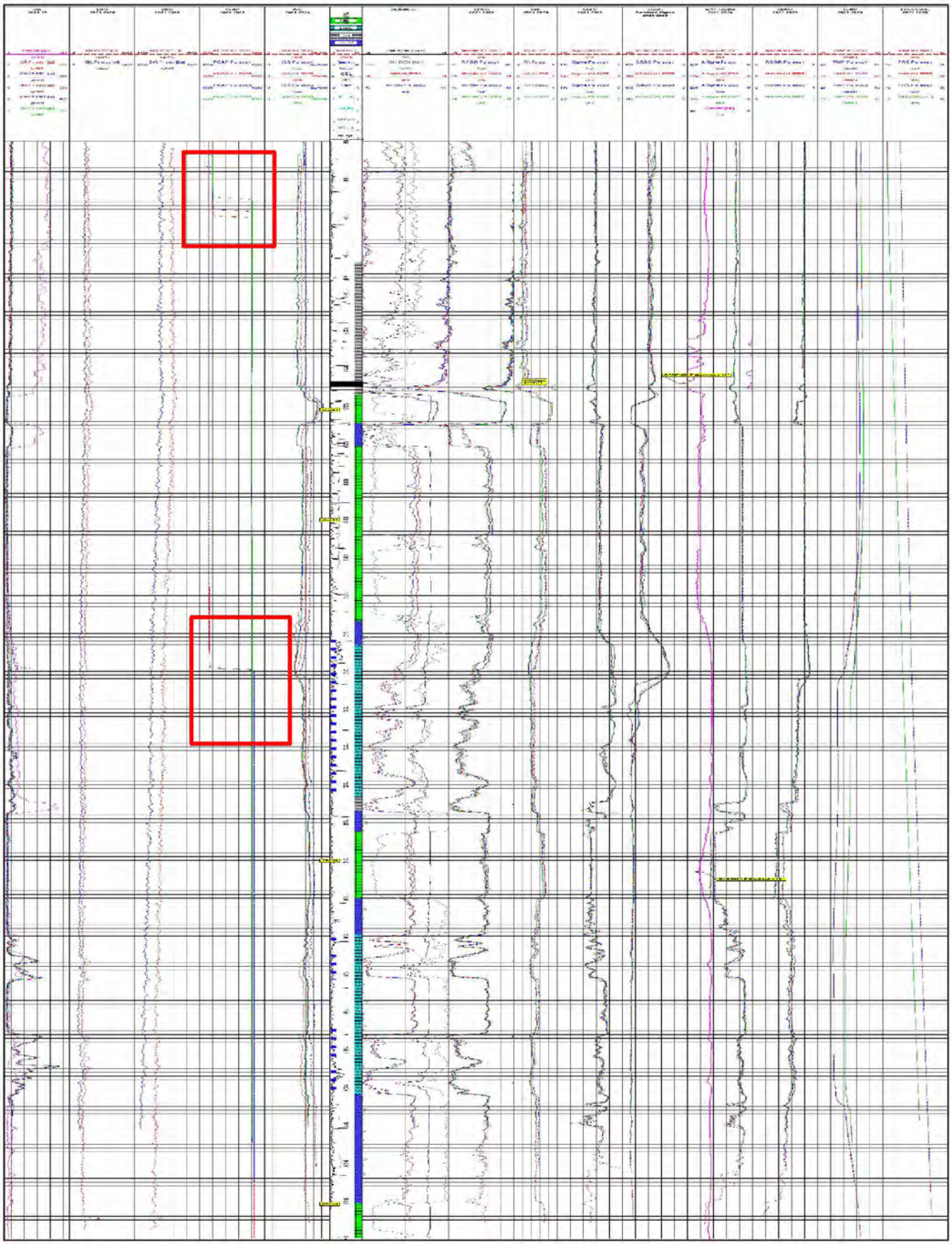

Figure 4: Row-7A composite comparison plot from 2021 and 2023 does not indicate relevant changes in salt layers. Only a fluid interface from water to gas is visible at 1170m from previous 2021 contact (Red rectangles)

Appendices

Well Schematics

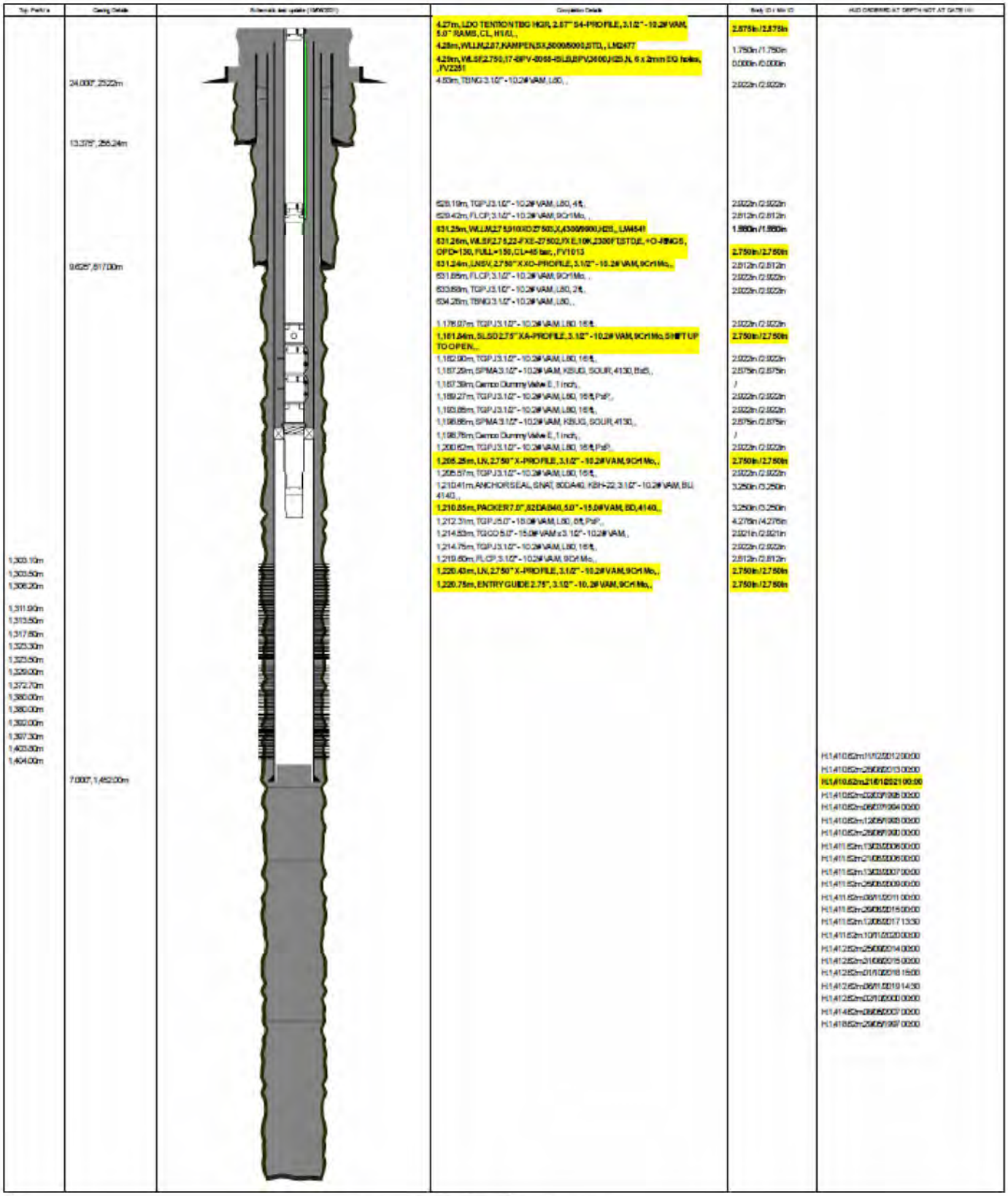

Fig 5: ROW-4 well schematic

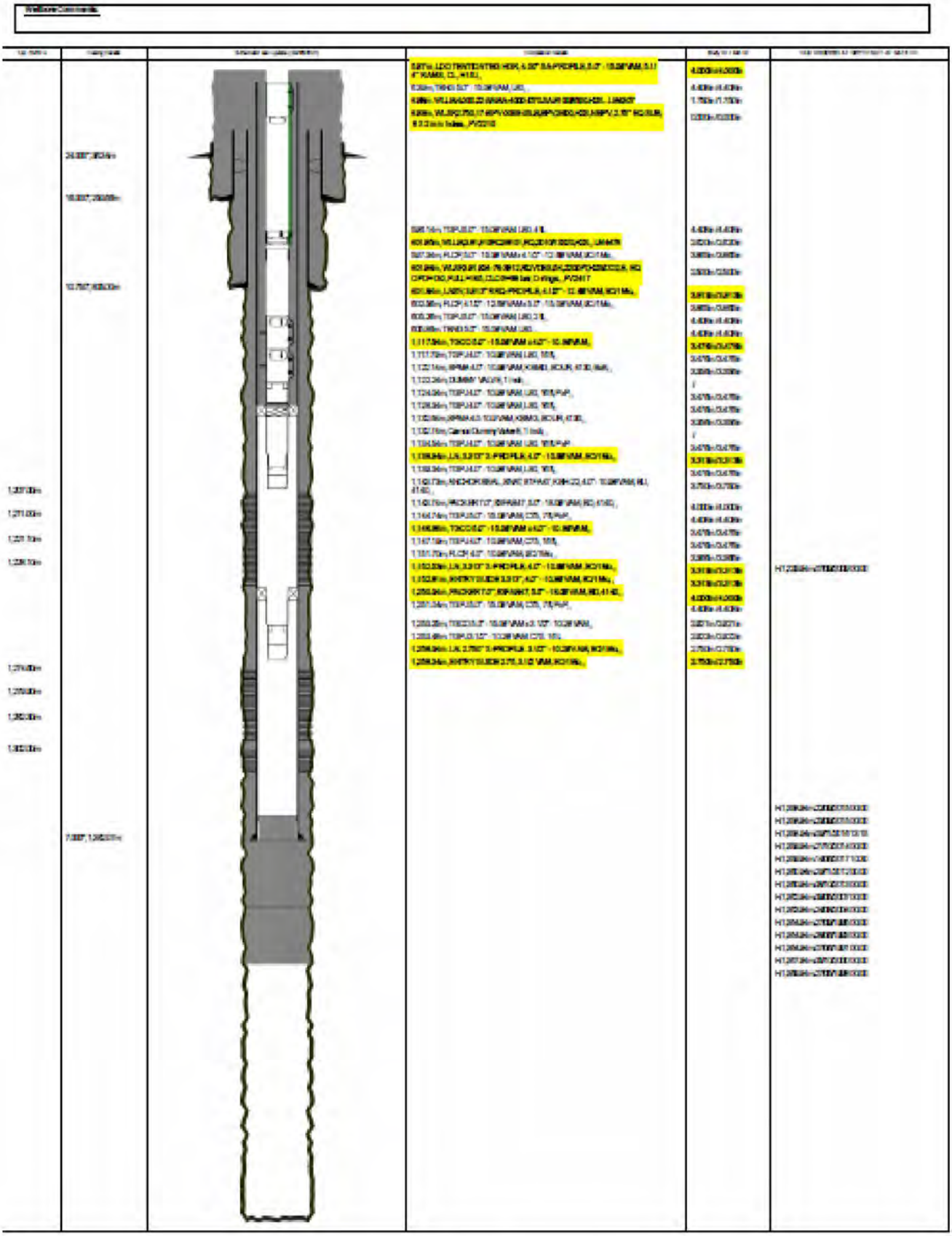

Fig 6: ROW-5 well schematic

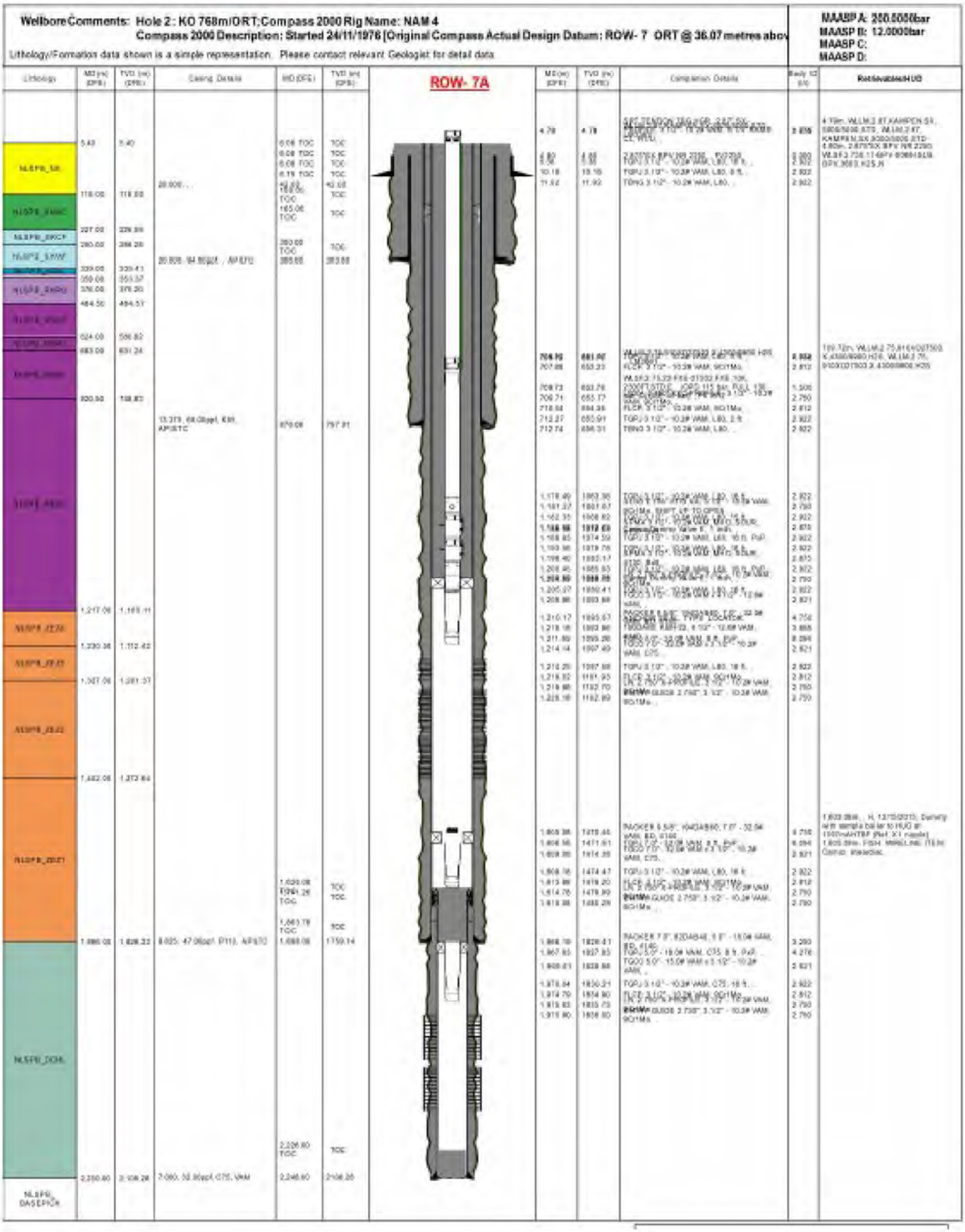

Fig 7: ROW-7A well schematic

Acquisition Specific Criteria

Due to the objectives and the risk assessment critical in this operation, it was agreed that Sigma curve logging should help to determine if low salinity Injection water was causing Salt dissolution in halite cap rock. Sigma curve is part of the Dual Detector Pulsed Neutron Capture mode (PNC2D), also including a number of other curves that can be used to aid in analysis (RATO, RIN, RICS, RBOR, RPOR) to help evaluate conditions (e.g. porosity, gas detection, completion changes, borehole fluid salinity, etc.). A standard PNC2D mode, one main log pass plus two repeat were acquired along specific intervals in wells ROW-4 , ROW-5 and ROW-7A (results shown in 2021 report) and repeat log executed in ROW-4 (results in this report)

No quantitative analysis was done for water saturation purposes. Some reference data were, however, required to validate tool response in function on formation and borehole environment. These were, specifically: total and/or effective porosity, shale volume, reference to limestone, dolomite, Anhydrite & Salt volumes, open hole caliper, fluid capacitance, temperature and cement logs.

Tool System Overview

The RPM instrument (figure 5) mounts three Sodium Iodide Crystals in his detection section, source energy output and additional, Casing Collar locator CCL, Gamma Ray GR and, optional, a Fluid Density or Fluid Capacitance modules. State-of-the-art detector electronics measure both the arrival time and energy of detected gamma rays.

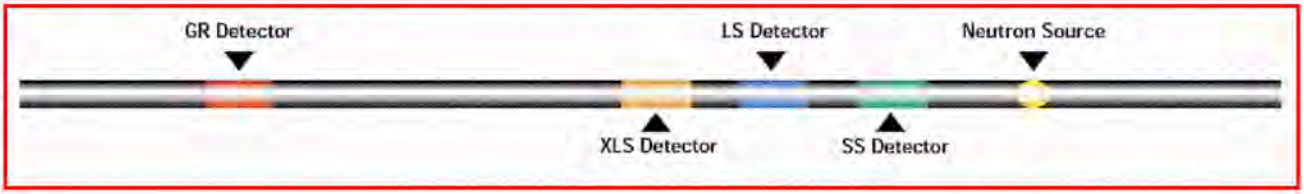

Fig 8: Pulsed neutron configuration

The generator pulses at distinct frequencies continuously generating fast neutrons that interact with environment components in different mode (fig.6). The detectors operate to receive energy gamma ray values (counts based) related to components based on different interaction (mainly Inelastic and Capture decay) to obtain the different logging measurements. The system is combinable with other production logging instruments, and is constructed in short modular sections for ease of shipping and handling.

Capture gamma - rays:

Hydrogen: 2.23 MeV
Iron: 7.65 MeV
Chlorine: 6.11, 1.95 MeV
Calcium: 6.41, 1.96 MeV
Silicon: 4.95, 3.54 MeV

Inelastic gamma - rays:

Carbon: 4.44 MeV
Oxygen: 6.13 MeV
Silicon: 1.78 MeV
Calcium: 3.34 MeV

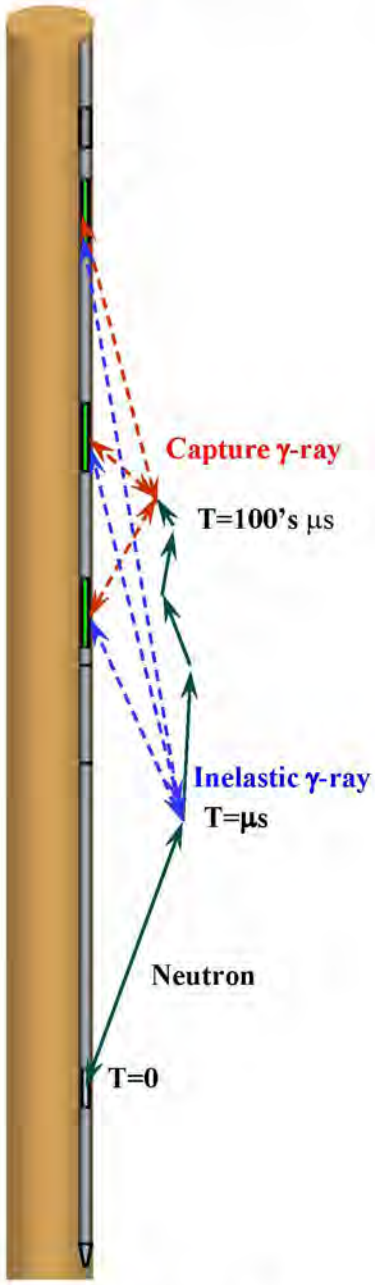

Fig 9: Neutron emission and interaction with environment

Operational Modes

Pulsed Neutron Capture Mode – (principal measurement is sigma, the thermal neutron absorption cross-section)

In the PNC logging mode, the neutron generator pulses at 1 kHz while the detectors record complete time spectra together with an energy spectrum used to monitor instrument Stability. Time spectra from short-spaced and long-spaced detectors can be processed individually to provide traditional thermal neutron capture cross-sectioned information. The two spectra can also be processed simultaneously to automatically correct for borehole and diffusion effects and produce results very near the intrinsic formation values. Advanced interpretation by use of third detector (PNC3D) data is available with the Baker Hughes GASVIEW evaluation program but not part of this logging program.

The RPM instrument enables reservoir monitoring and management by offering the following capabilities:

- Monitoring of fluid contacts
- Time lapse fluid monitoring
- Gas/oil/water differentiation and contact level identification
- Production and reservoir depletion
- Enhanced oil recovery projects
- Future reservoir management base logs
- Production/injection profiling in multi-string completions
- Three-phase fluid holdups

These will not be discussed here as they have no relevance in connection with this logging campaign.

MNEMONICS (Curve Description)

PNC Mnemonics

GR .GAPI	: Gamma Ray counts
ILS .CPS	: Inelastic LS Count rate energy window .4-8.8 MeV
ISS .CPS	: Background Subtracted Inelastic Short Space
LS .CPS	: Long Spaced Detector Counts
RATO . ----	: Ratio from PDK SS/LS
RBOR . ----	: Short Spaced Elastic Count rate Ratio (GE1S/GE2S)
RICS . ----	: SS Inelastic to Capture count rate Ratio (ISS/CSS)
RIN . ----	: Ratio of background subtracted ISS/ILS
RPOR .PU	: RATO Porosity (Neutron Porosity)
SGFC .cu	: Formation Corrected Sigma
SPEED .mpm	: Cable Speed
SS .CPS	: Short Spaced Detector Count rate
SW1 . %	: Water Saturation (SIGMA)
TEN .LBF	: Differential Tension
TIME .S	: Elapsed Time - stationary pressure measurements
TTEN .LBF	: Total Tension
BKL .CPS	: Background Long Space counts
BKS .CPS	: Background Short Space counts
CCL . mV	: Casing Collar Locator

Auxiliary Mnemonic *(surface to HUD)*

DEPT .FT	: Depth
DEV .DEG	: Deviation Angle
FCAP .CPS	: Fluid capacitance
FDEN .	: Fluid Density
GR .GAPI	: Gamma Ray counts
TEMP .deg	: Temperature
QDPRES .atm	: Pressure