Assignment

Submitted To

Department of Applied Geophysics

Subject: WELL LOGGING and ELECTROFACIES ANALYSIS

By

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1. <u>Onset Overview of Overpressure:</u>

To do overview of Overpressure we need to follow some basic steps, which are describe bellow.

a. Exploratory Data Analysis (EDA).
b. Smooth the data set.
c. Lithology identification.
d. Volume of shale calculation.
e. Differentiate data set according to GR log value for shale and sand zone.
f. Plot the relevant log to identify the overpressure zone.

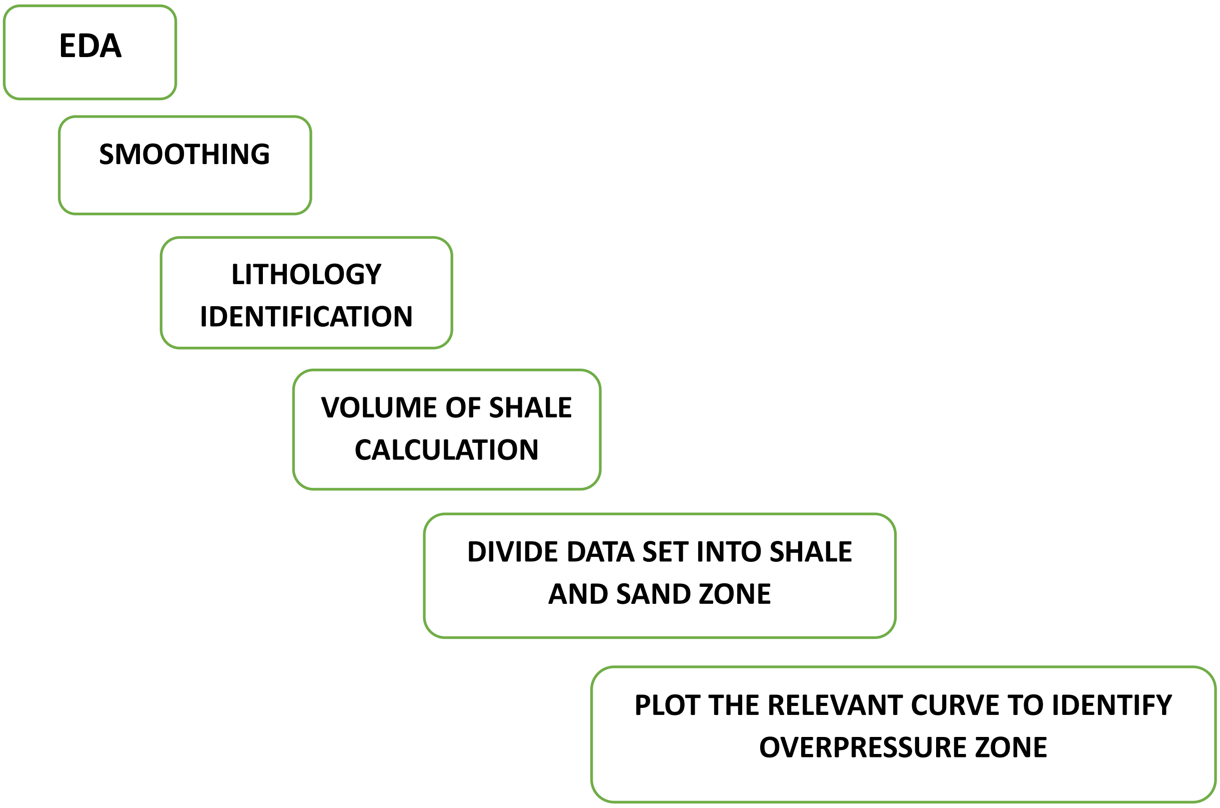


Figure 1: Block diagram of steps

a. **EDA:**

It is a very crucial part of any study or analysis. In this part I am going to do data qc, which is very much important because I need the correct data to know the correct information.

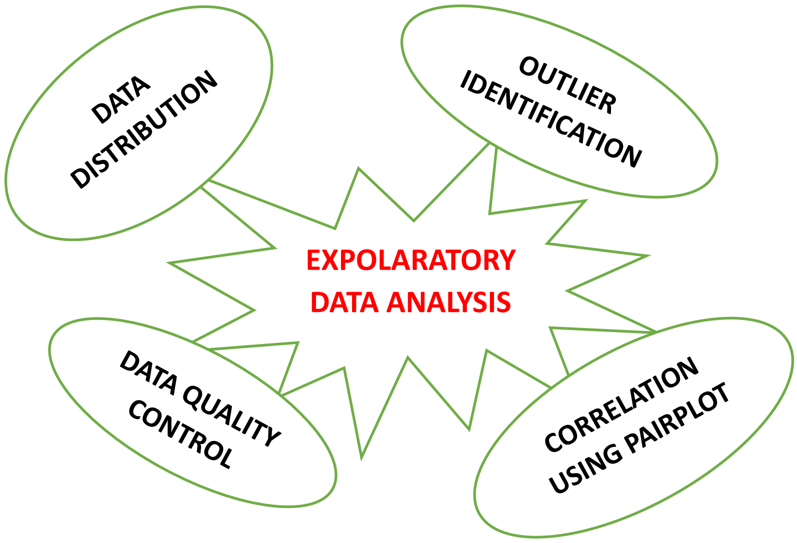


Figure 2: Block diagram of EDA

Data Distribution:

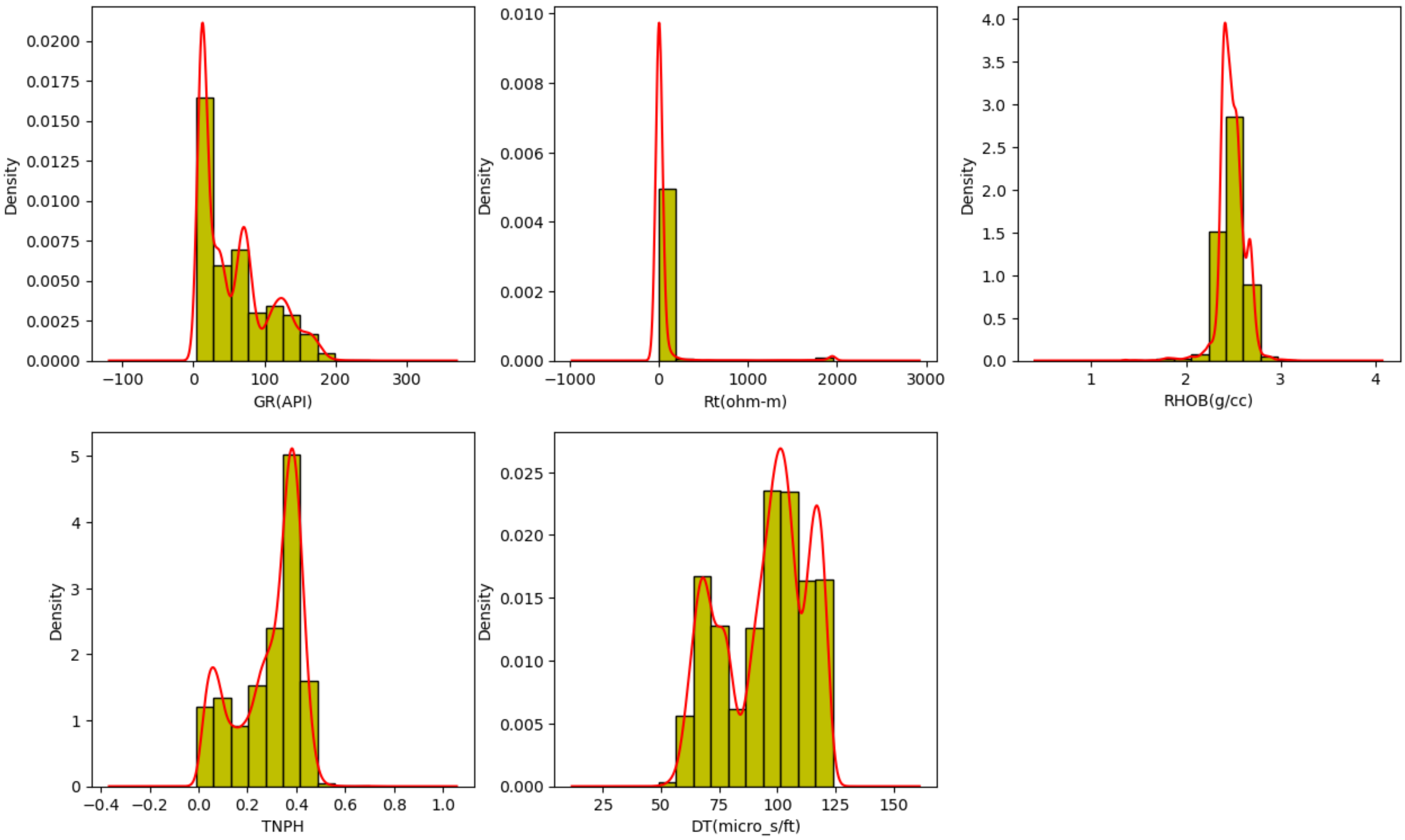


Figure 3: Data distribution using histogram plot

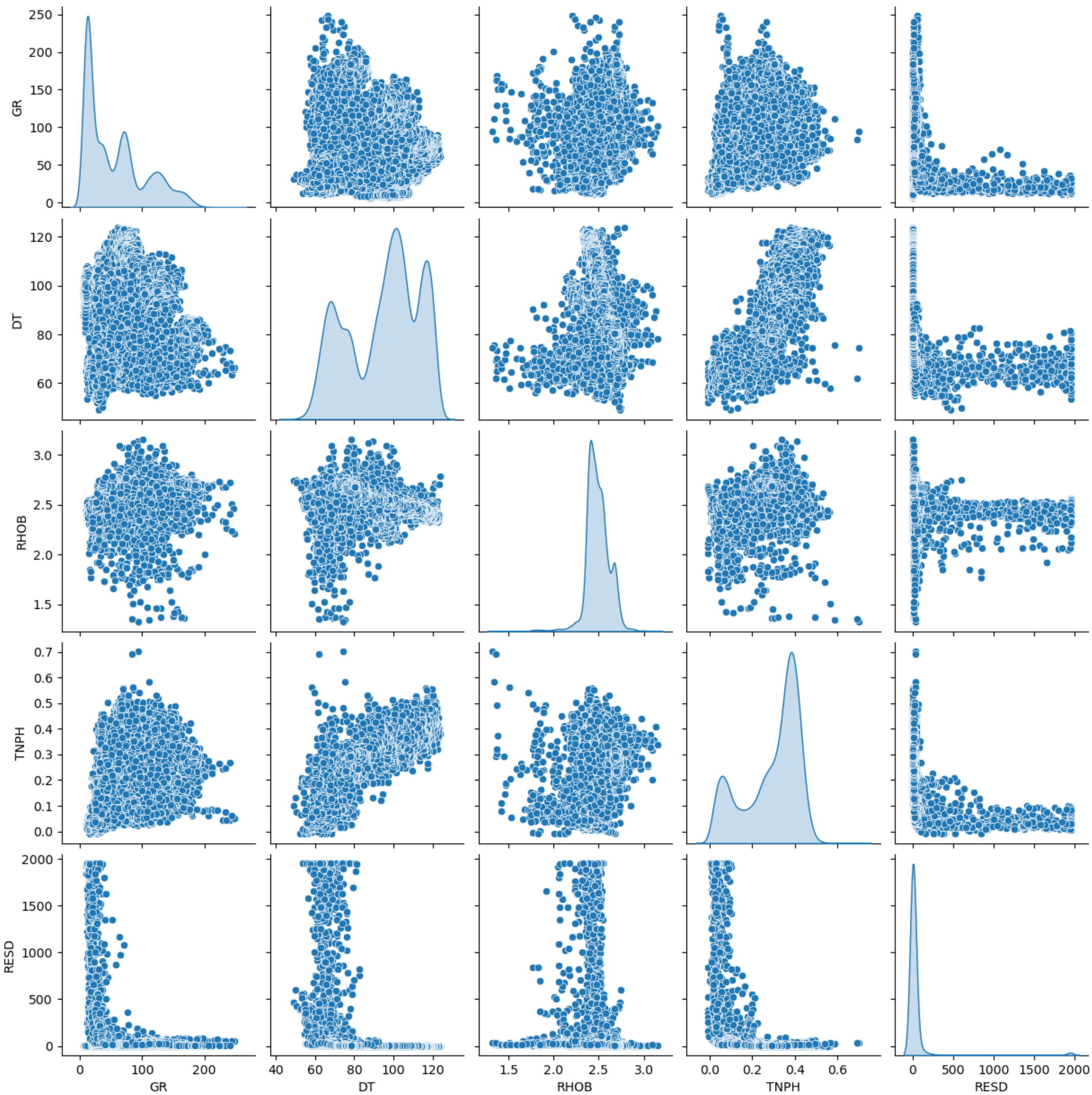


Figure 4: Data distribution using pair-plot

Comments:

From these two types of plots, I can say that

- GR data is not distributed in proper gaussian manner, it is bit skewed like distribution.
- DT, RHOB and TNPH all are distributed in gaussian fashion.
- RESD having skewed like distribution.

Outlier Identification/ QC:

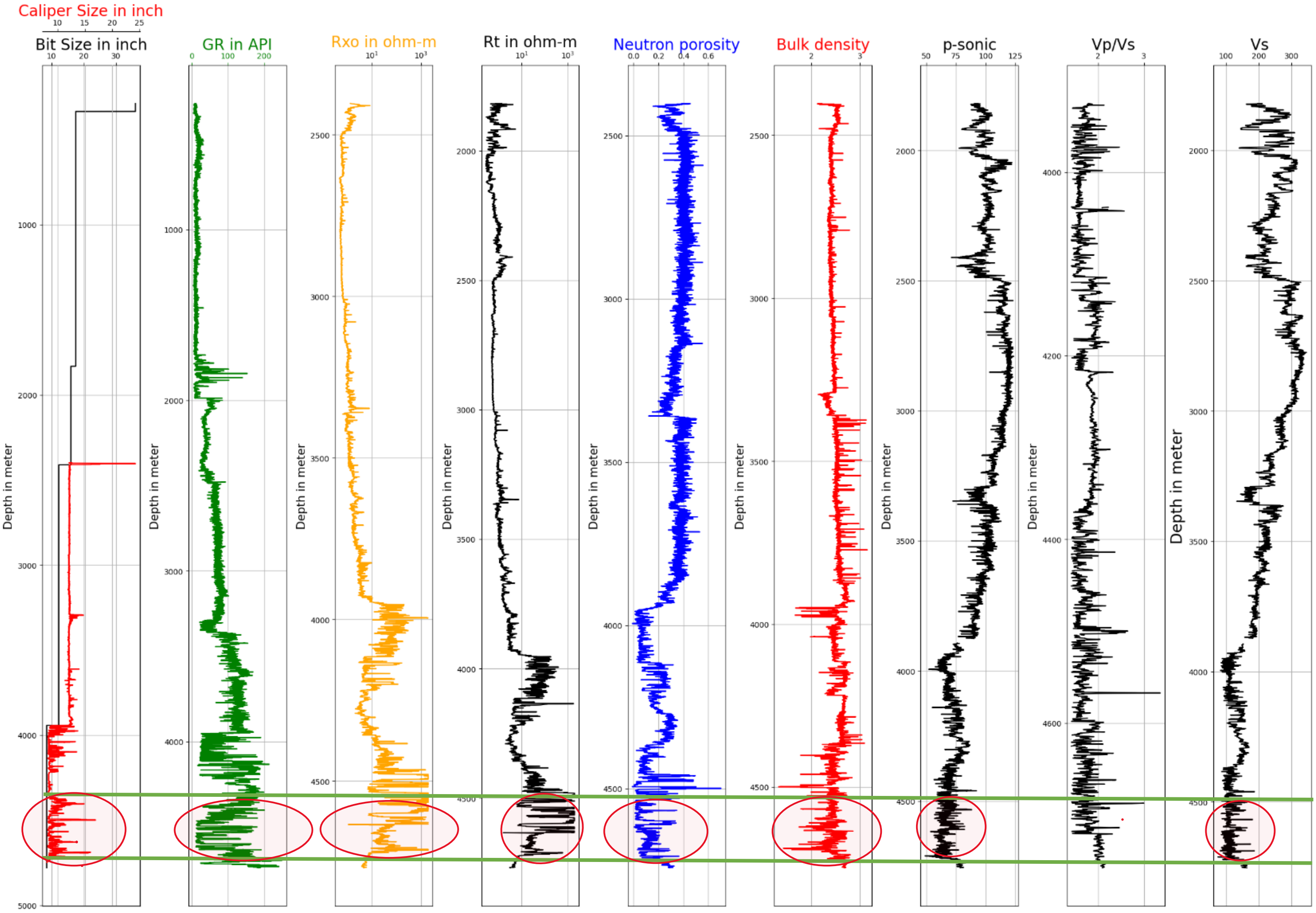


Figure 5: Bad borehole marked according to calliper response

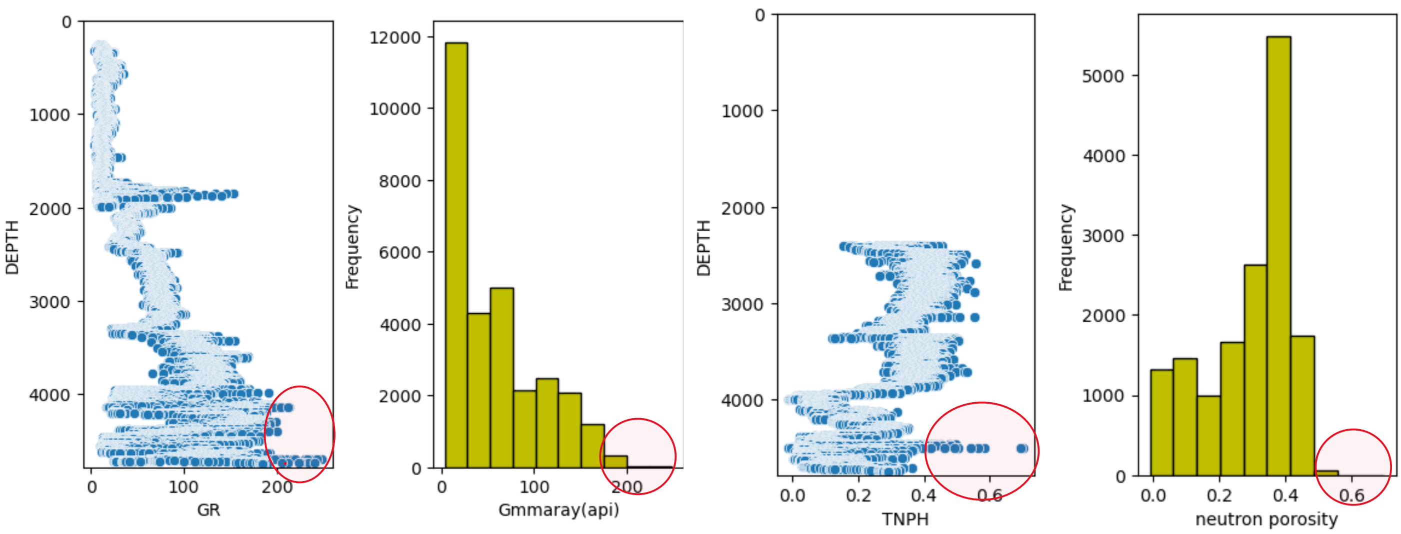


Figure 6: Bad data identification of GR and TNPH data

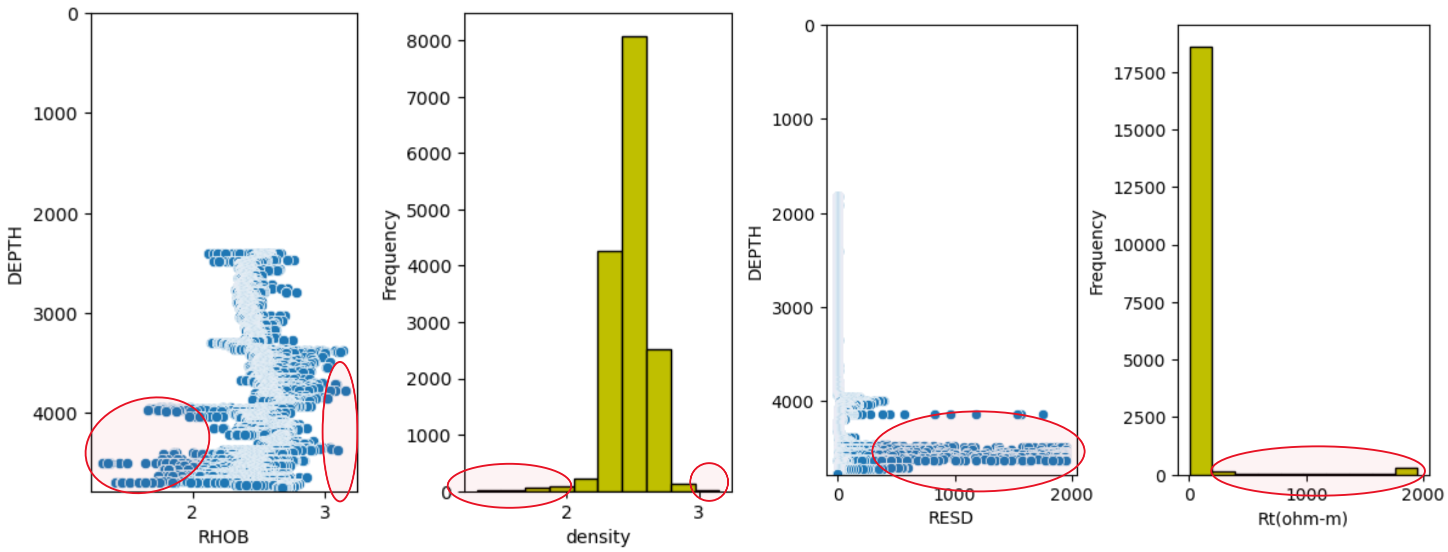


Figure 7: Bad data identification of RHOB and RESD data

Comments:

- we know that if calliper log having higher and lower value than bit size of .5 inch then that zone identified as bad borehole zone. From figure 5 I can easily say that below 4000 m data is little bit affected by Bad borehole condition.
- GR having few values which are greater than 200 api, having lower frequency of occurrence. Those value identified as an outlier not because of bad borehole it might be happen because of tool malfunction because I know that GR tool is not padded kind of tool.
- Below 4000m porosity value affected by bad borehole. It showing higher value of porosity which having lower frequency of occurrence, it might be happen because of bad borehole and because of that I get fake porosity.
- Below 4000m RHOB having values lower than 2 and also higher than 3, frequency of occurrence of those values are very low. It might be occurring because of bad borehole.
- RESD values below 4000m having low frequency of occurrence.

Data Correlation:

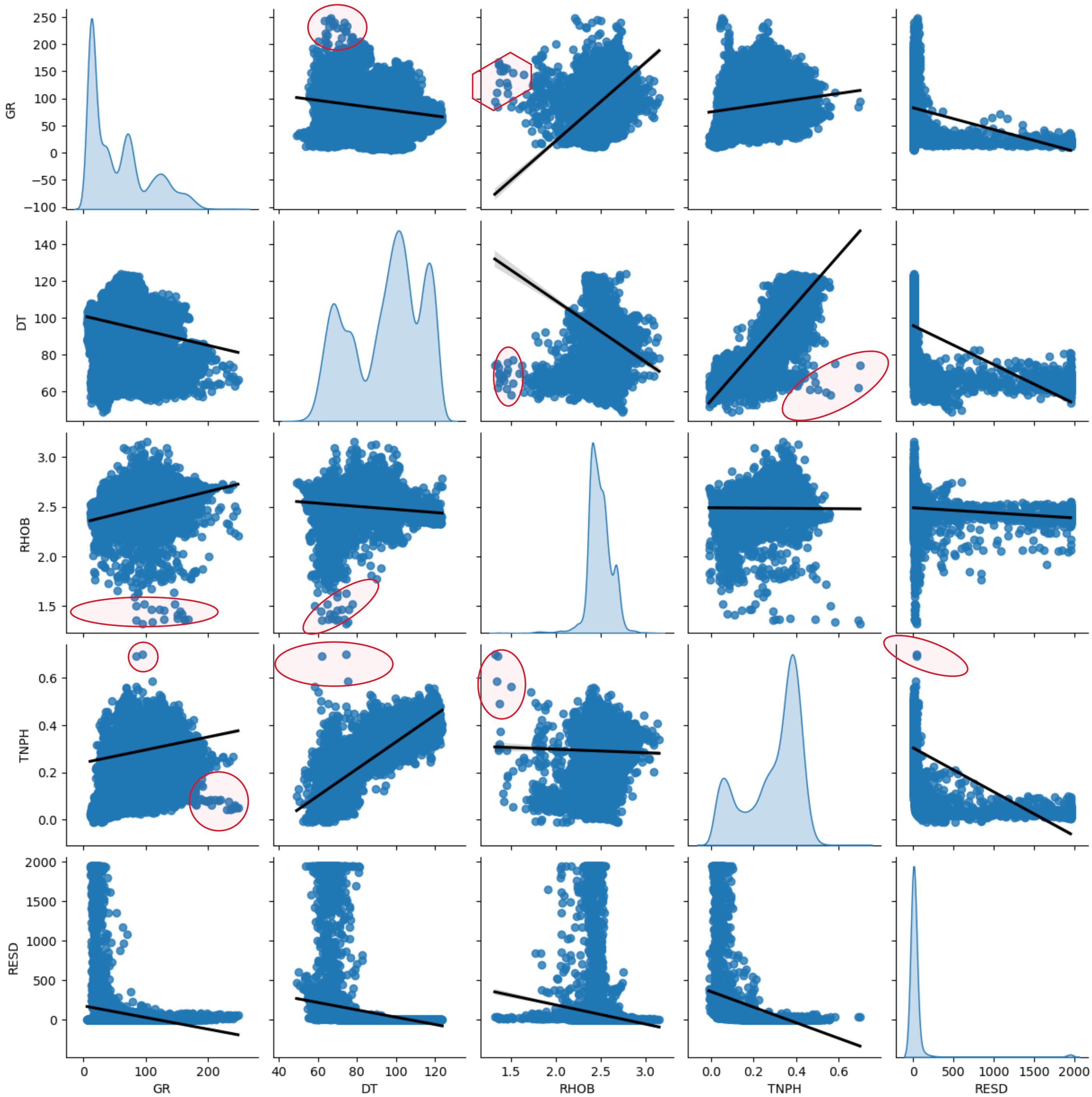


Figure 8: Correlation between different data set using pair-plot

Comments:

- From this fig I can easily say which one having positive correlation with which one
- Red circles are nothing but treat as outliers.

b. Smoothing:

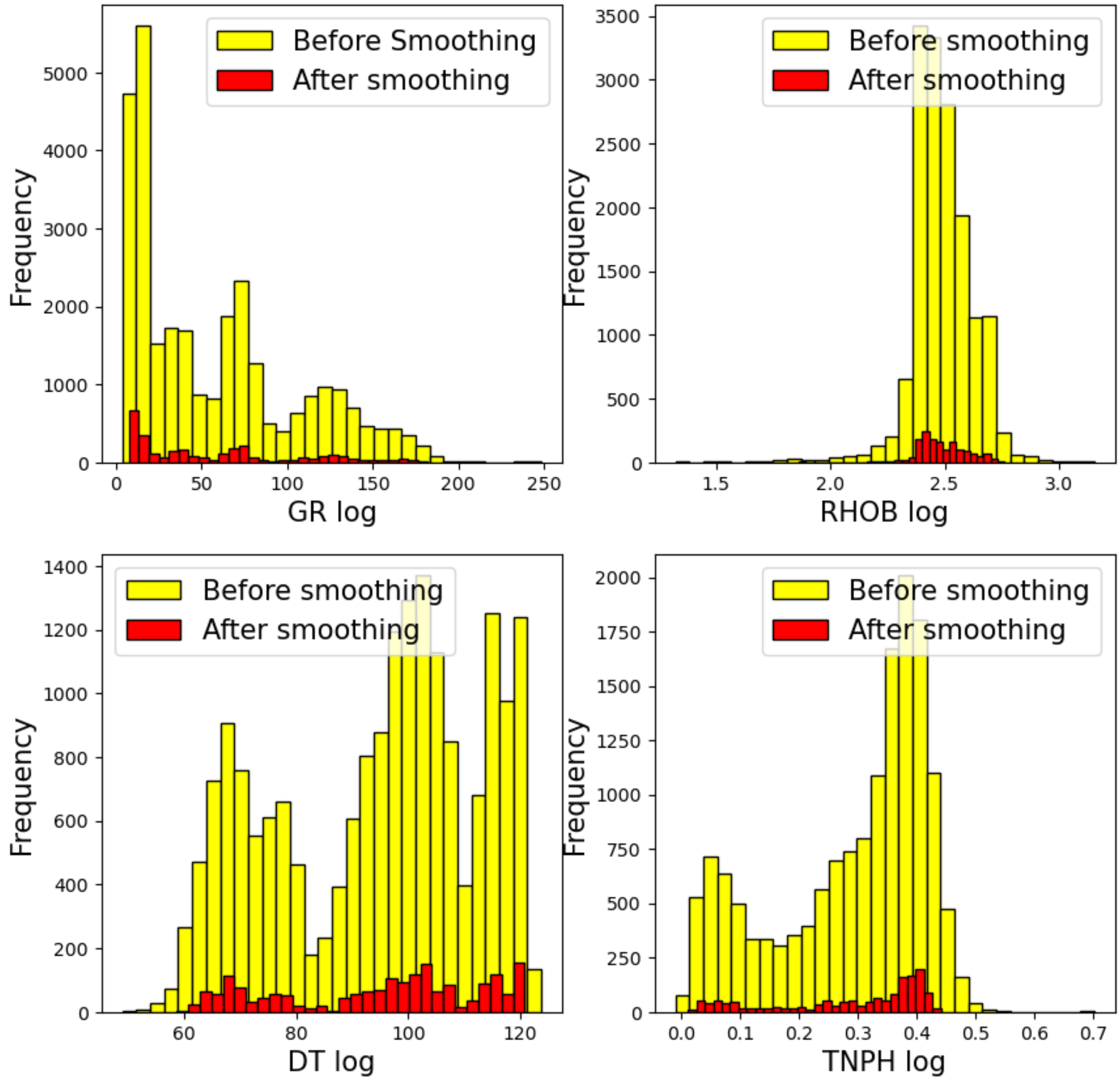


Figure 9: Before and after scenario of data smoothing

Comments:

- To get a smooth curve instead of rough curve I did smoothing.
- To see the figure 9, I can say that after smoothing data having no outliers which are identified previously.
- More important is that nature of data distribution is not change any more.

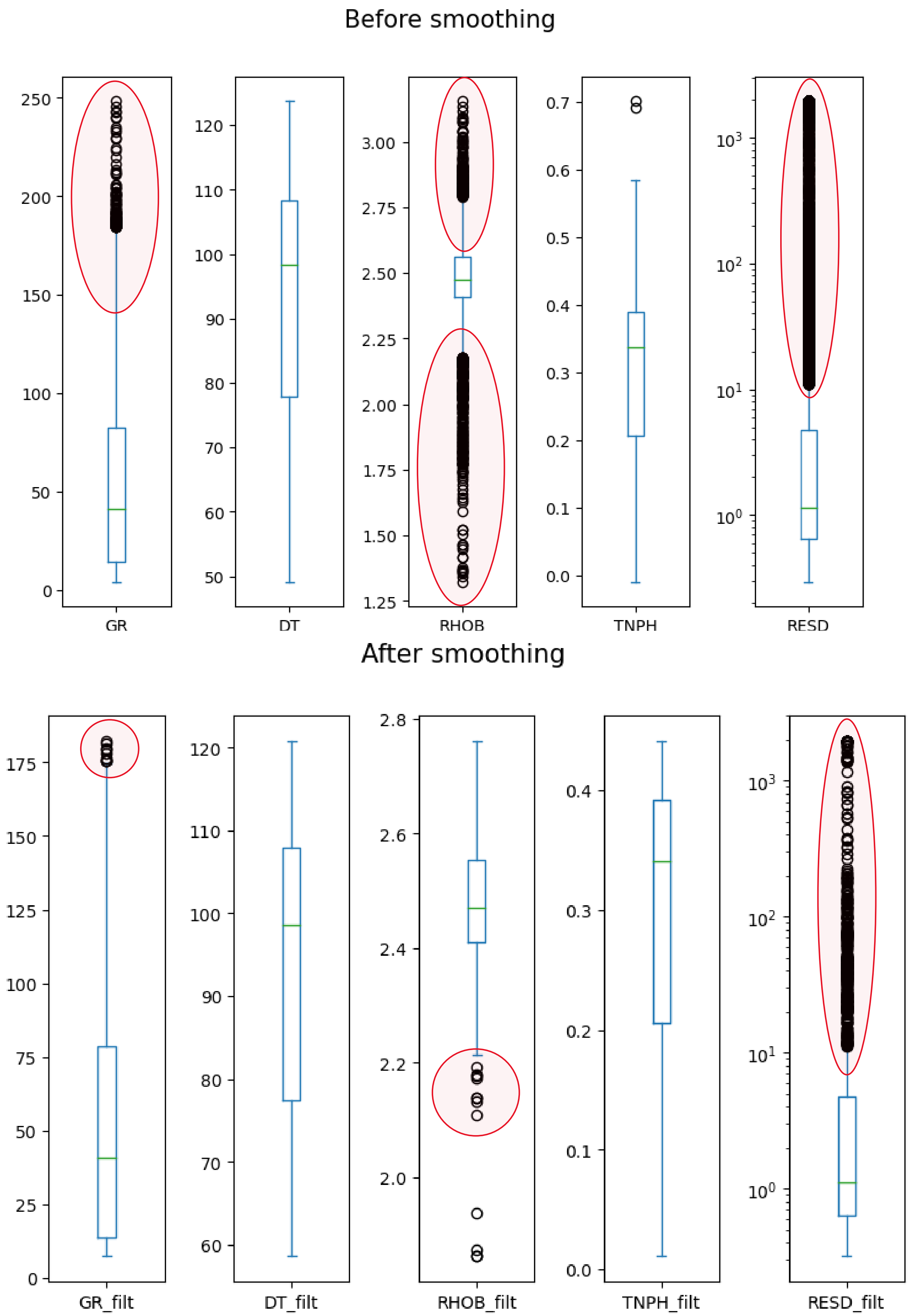


Figure 10: Compare the data distribution before and after smoothing scenario using box plot

c. Lithology Identification:

From the given marker information, I can say about lithology.

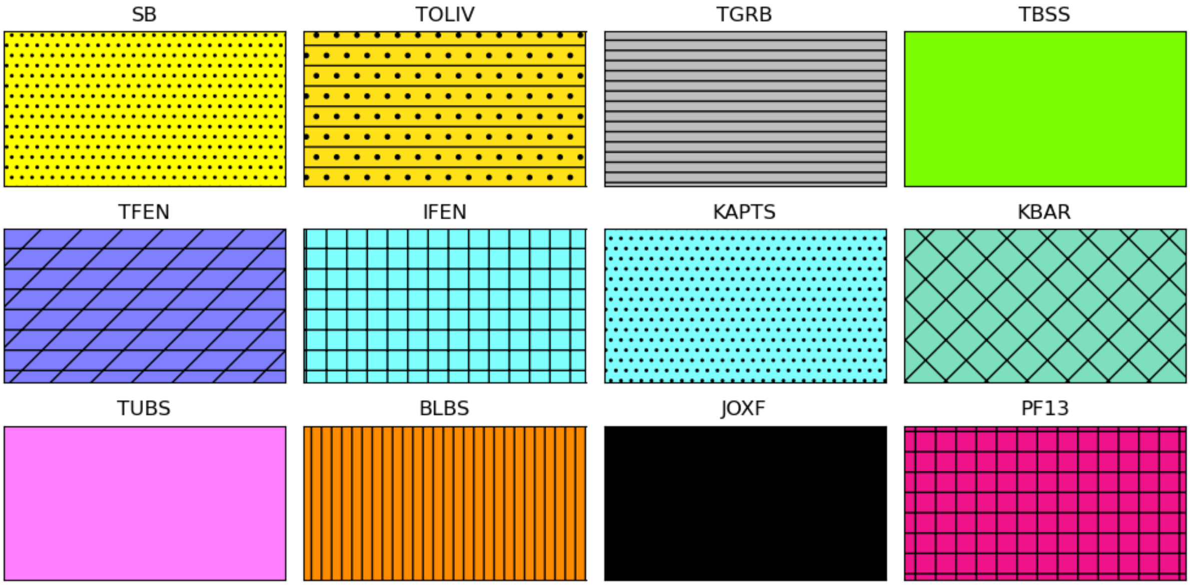


Figure 11: Given marker info plot

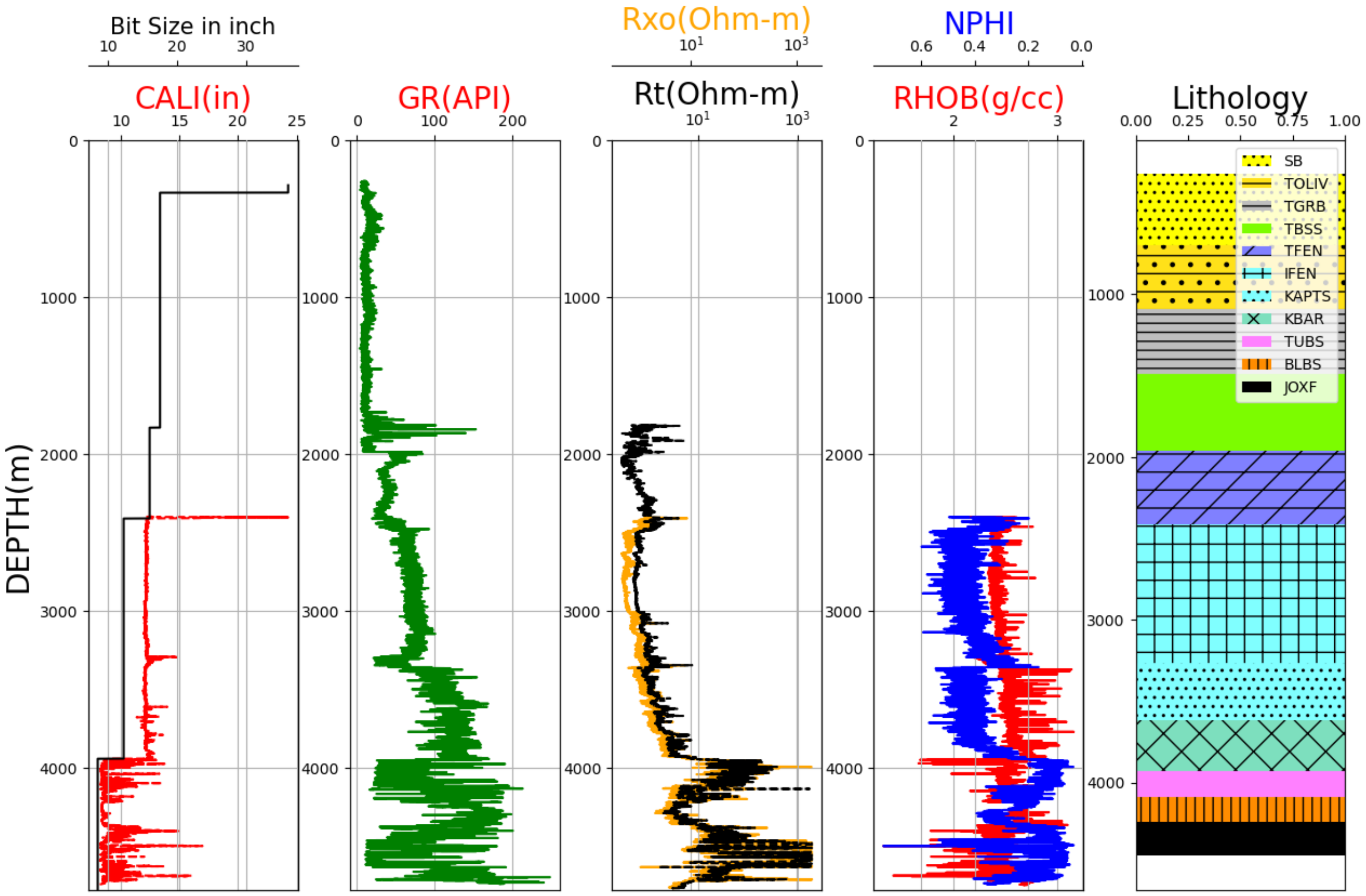


Figure 12: Lithology plot along with another log

d. Volume of shale calculation:

I know the formula by which I can get the Gamma-ray index and then if I correct this Gamma-ray index for particular age of the formation rock then I get the volume of shale.

Igr = (GR_log – GR_min)/(GR-max – GR_min)

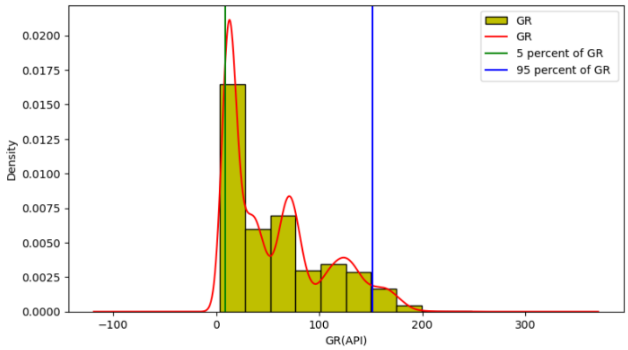
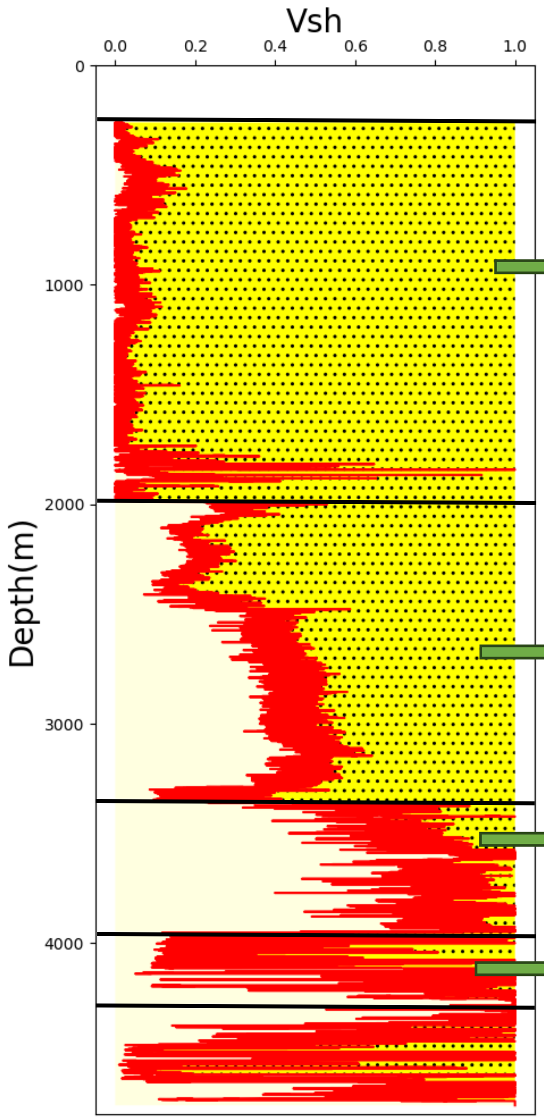


Figure 13: GR log histogram to find 5% & 95%

Where GR_log is the log data in particular depth interval, GR-min is the 5% of the log data and GR_max is the 95% of the log data.



Volume of shale is very low in this zone

Volume of shale is increasing in this zone

Volume of shale is increasing in this zone

It also indicating high Vsh.

Figure 14: volume of shale w.r.t. depth

e. Divide data according to GR/Vsh:

To differentiate the data into shale zone and sand zone I took that GR values greater than equal to 60 then it is read as shale zone and below this value it indicates the sand zone.

NOTE: I did this differentiate because my aim is to identify the overpressure zone and I know that overpressure zone occurs mostly in the shale dominated zone.

Comments:

- I can clearly see that shale zone started from 2500m(nearly)

NOTE: This GR curve exactly mimics the fig 14, Vsh curve.

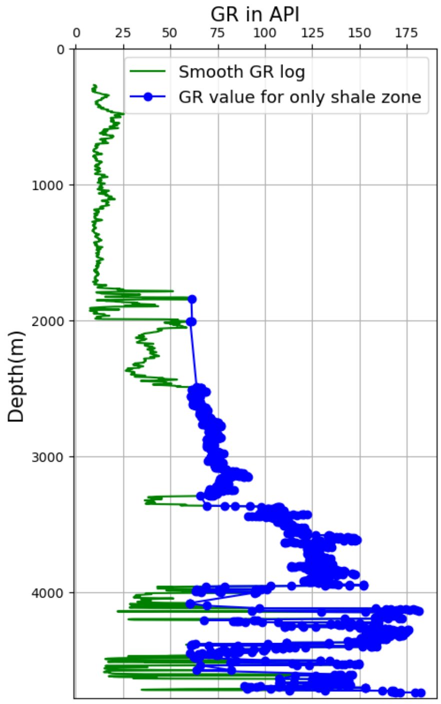


Figure 15: Shale and Sand zone differentiate based on GR

f. Overview of onset Overpressure:

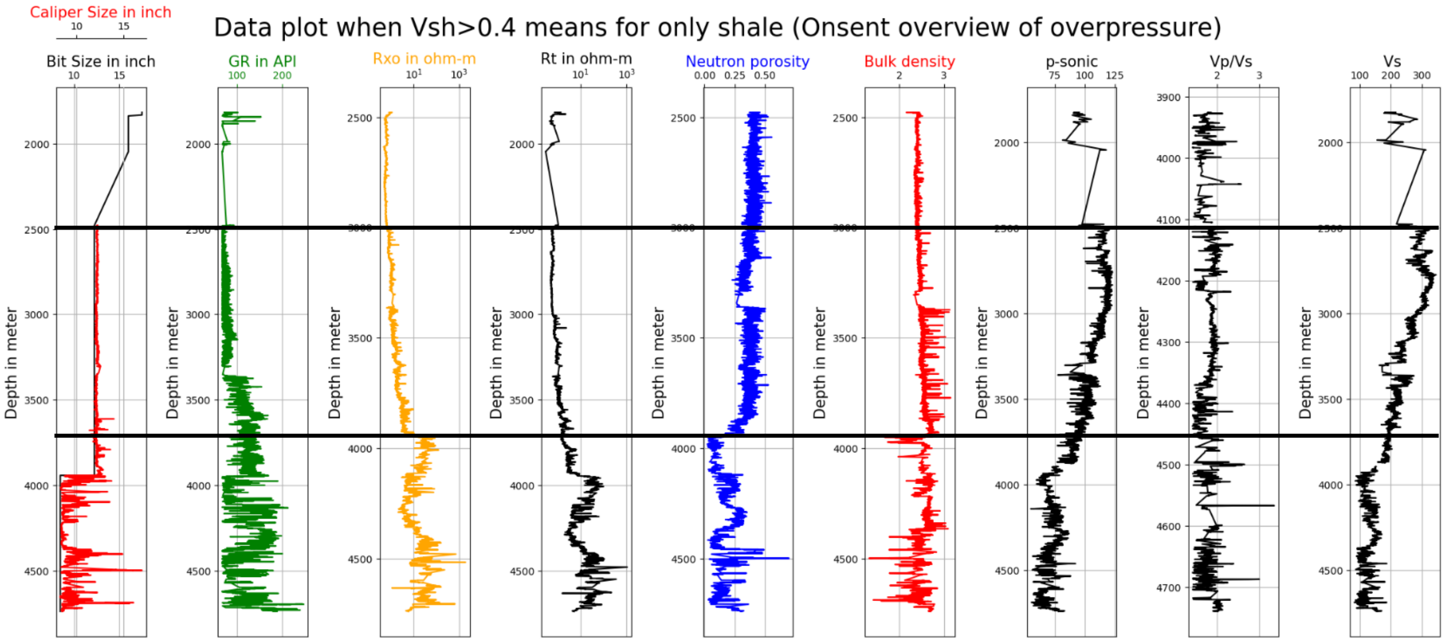


Figure 16: Overpressure zone identification from the shale zone data plot

Comments:

I choose this marked zone as an overpressure zone because:

- GR values are very high it is shale zone.
- Porosity values are also very high in this zone.
- Resistivity decreases in this zone.
- P_sonic increases as well in this zone.

ONSET OVERPRESSURE ZONE PREDICTION USING POROSITY DATA:

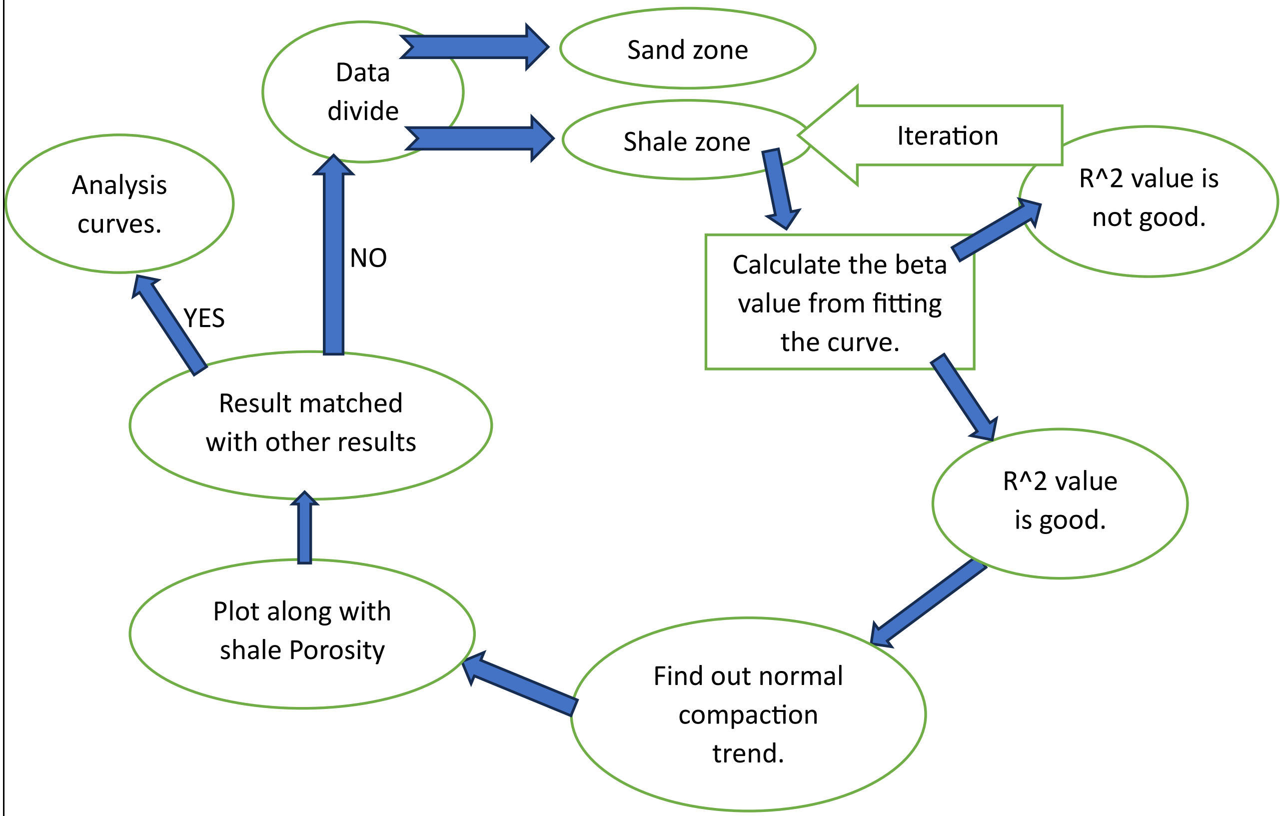


Figure 17: Block diagram of Overpressure zone identification using Porosity data through iterative process.

BETA value:

To find out the beta value I am using OLS regression method.

I get the value is 0.0007240833695897205.

OLS Regression Results:

OLS Regression Results			
Dep. Variable:	DEPTH	R-squared (uncentered):	0.919
Model:	OLS	Adj. R-squared (uncentered):	0.919
Method:	Least Squares	F-statistic:	1.588e+04
Date:	Thu, 07 Mar 2024	Prob (F-statistic):	0.00
Time:	10:58:43	Log-Likelihood:	-11649.
No. Observations:	1396	AIC:	2.330e+04
Df Residuals:	1395	BIC:	2.331e+04
Df Model:	1		
Covariance Type:	nonrobust		

Comments:

- These two identified zones having higher pressure, because of porosity is deviated from the normal compaction trend and it is not reduced with depth.

Mathematical formula:

NCTL porosity: $\phi_n = \phi_0 e^{-cz}$

$$\varphi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{fl}}$$

Where,

ρ_{ma} = the density of the rock matrix

ρ_b = the bulk density of formation [from log]

ρ_{fl} = the density of pore fluid

Φ = total porosity

NOTE: shale density=2.56g/cc, sand density=2.65g/cc, fluid density=1g/cc.

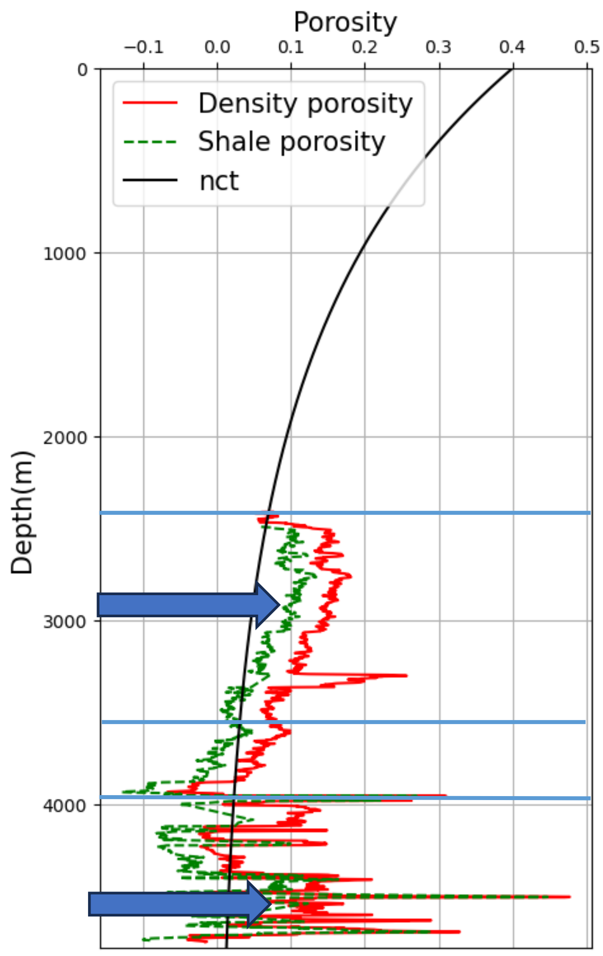


Figure 18: Overpressure Zone identification using porosity plot

2/a. **Pore Pressure Calculation:**

Mathematical relations:

Hydrostatic pressure $P^{hyd}{}_p(z) = \int_0^z \rho_w(z)gdz \sim \bar{\rho}_w g z_w$

Hydrostatic pressure gradient $P_g^{hyd} = \dfrac{P_p^{hyd}}{z}$

[Zhang, 2019]

Eaton's Method by POR (I type)

Derivation of pore pressure prediction from porosity

Relation between the porosity and effective stress:

(1) $\phi = \phi_0 e^{-a\sigma_{eff}}$ ⇒ (2) $\sigma_{eff} = \frac{1}{a}\ln(\frac{\phi_0}{\phi})$

(3) $\phi = \phi_0 e^{-a\sigma_n}$ ⇒ (4) $\sigma_n = \frac{1}{a}\ln(\frac{\phi_0}{\phi_n})$

(5) $\dfrac{\sigma_{eff}}{\sigma_n} = \dfrac{\ln\phi_0 - \ln\phi}{\ln\phi_0 - \ln\phi_n}$ ⇒ (6) $\sigma_{eff} = \sigma_n \dfrac{\ln\phi_0 - \ln\phi}{\ln\phi_0 - \ln\phi_n}$

The effective stress and pore pressure relation:

(7) $P_p = (\sigma_v - \sigma_{eff})/\alpha$ (8) $\sigma_n = \sigma_v - \alpha P_n$

Substituting (6), (7), (8): $P_p = (\sigma_v - \sigma_{eff})/\alpha = (\sigma_v - \sigma_n \frac{\ln\phi_0 - \ln\phi}{\ln\phi_0 - \ln\phi_n})/\alpha = [\sigma_v - (\sigma_v - \alpha P_n)\frac{\ln\phi_0 - \ln\phi}{\ln\phi_0 - \ln\phi_n}]/\alpha$ (9)

NCTL porosity: $\phi_n = \phi_0 e^{-cZ}$ (10)

(10) into (9): $P_p = [\sigma_v - (\sigma_v - \alpha P_n)\dfrac{\ln\phi_0 - \ln\phi}{\ln\phi_0 - \ln(\phi_0 e^{-cZ})}]/\alpha = [\sigma_v - (\sigma_v - \alpha P_n)\dfrac{\ln\phi_0 - \ln\phi}{cZ}]/\alpha$ (11)

$$\boxed{PPG = [OBG - (OBG - \alpha HSG)\frac{\ln\phi_0 - \ln\phi}{cZ}]/\alpha} \quad (12)$$

Overburden Pressure

For onshore

$S_v(z) = \int_0^z \rho(z)gdz \sim \bar{\rho}gz$

where *ρ(z)* is the formation density at depth *z* obtained from the density logs; *g* is the gravitational acceleration *g* = 9.80 m/s²

For offshore

$S_v(z) = \rho_w g z_w + \int_{z_w}^z \rho(z)gdz \sim \bar{\rho}_w g z_w + \bar{\rho}g(z-z_w)$

where ρ_w is the formation density of water at depth z_w.

- Take alpha is equal to 1 for mathematical simplification.

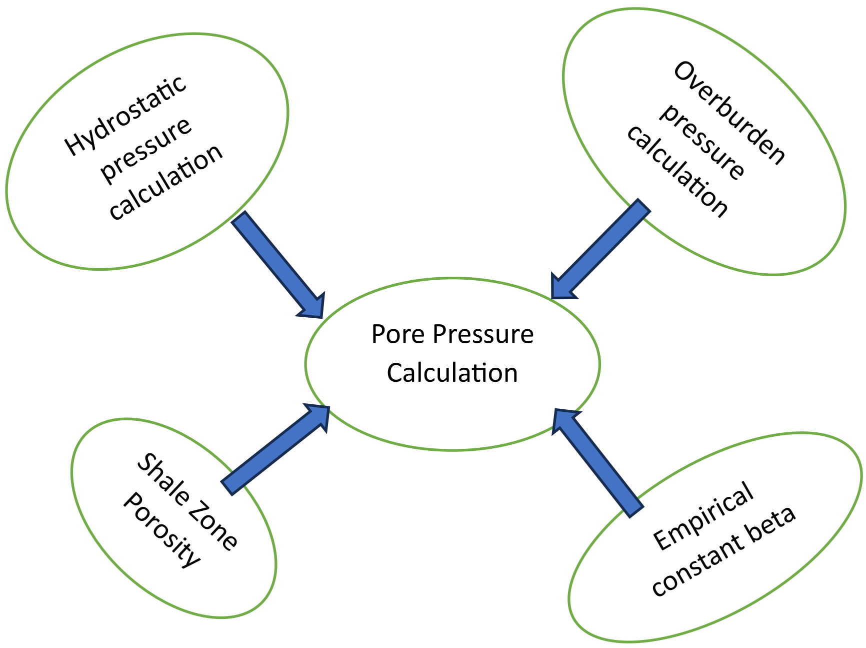
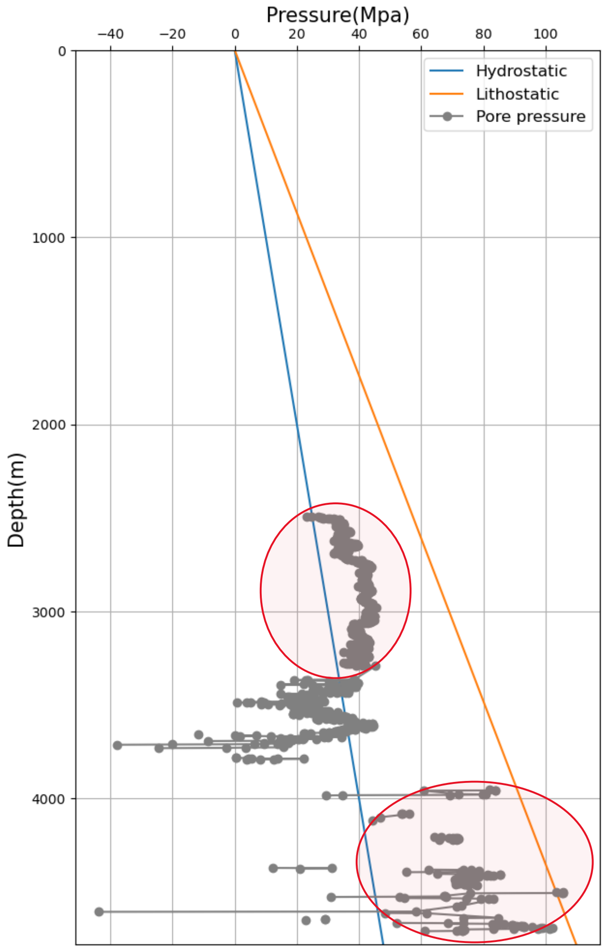


Figure 19: Block diagram of needed information to calculate Pore Pressure.

Steps:

I. Smooth the data set.
II. Calculate hydrostatic and lithostatic pressure.
III. Divide the data into shale zone and sand zone.
IV. Calculate empirical constant beta.
V. Calculate Normal compaction trend.
VI. Find out the overpressure zone using porosity curve in shale zone.
VII. Find out shale porosity in the shale zone.
VIII. Find out the pore pressure using all the information.



Comments:

- Two marked zone having high pressure because those zones having pore pressure which Is higher than the hydrostatic pressure and close to the overburden pressure.

2/b. **Magnitude of Overpressure:**

To calculate the magnitude of overpressure we need to know the value of hydrostatic pressure and pore pressure, the magnitude of overpressure is nothing but the difference between pore pressure and the hydrostatic pressure.

Comments:

- Some values are negative because at those place pore pressure is less than the hydrostatic pressure.

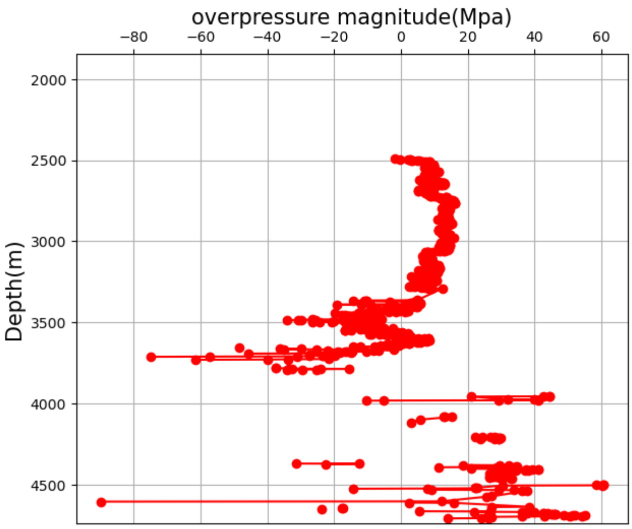


Figure 20: Magnitude of an overpressure

2/c. **Mechanism for overpressure:**

High pore pressure accrues due to compaction and unloading in general.

Compaction:

It is nothing but disequilibrium compaction. It is occurred because of

- Basin subsidence takes place very quickly.
- Thickness of clay/shale layer is high.
- Permeability is very low.

Basically, shale is not able to displace more water.

Unloading:

The clay/shale zone has undergone on uplifted. It is occurred because of

- Fluid generation inside the clay/shale formation.
- Fluid migration path is not available.

Shale can be refilled with fluid and a high-pressure zone is created without large increase in porosity.

Evidance-1: Vp vs Effective stress and density vs effective stress.

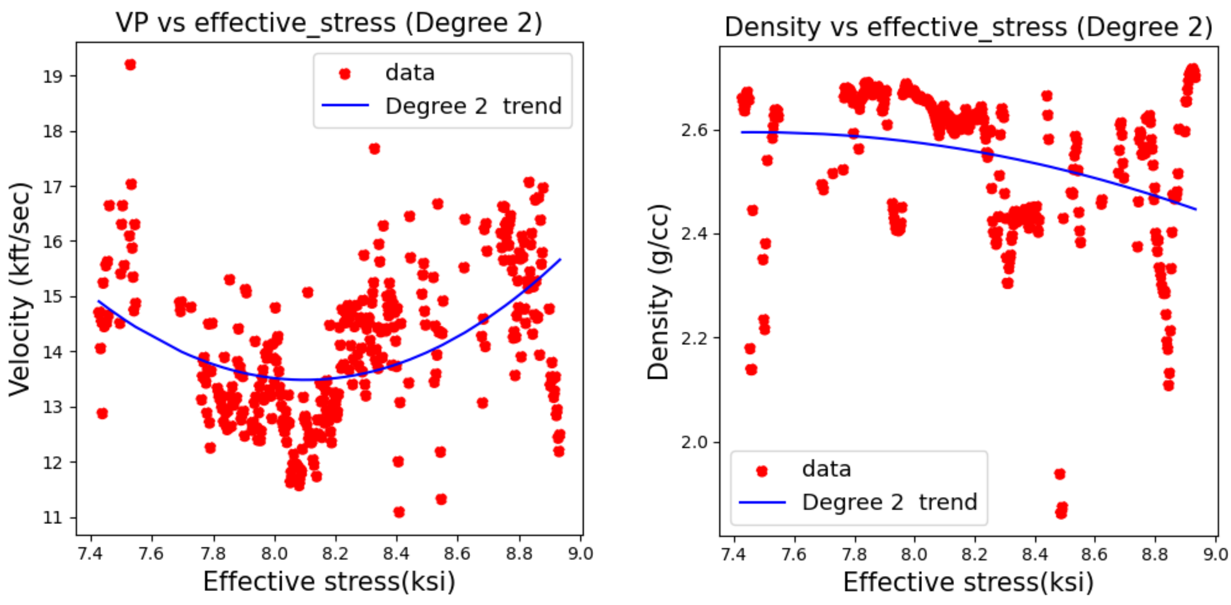


Figure 21: plot for predict the overpressure mechanism

Comments:

- In velocity vs effective stress curve showing that velocity drops to increase of stress.
- In density vs effective stress curve showing that density is not much changing with stress.

- I can say that the mechanism behind the overpressure might be “Unloading”.

Evidence-2: velocity vs density.

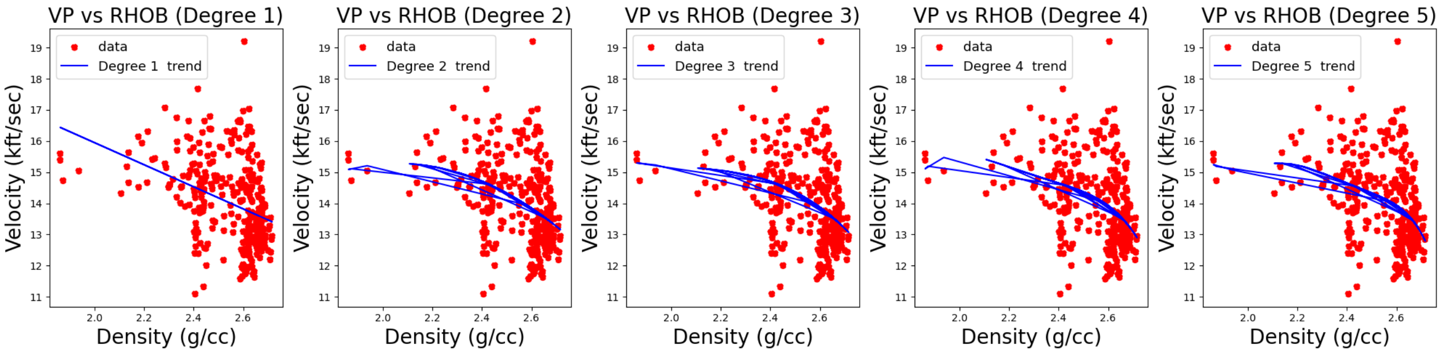


Figure 22: velocity vs density curve to know the overpressure mechanism

Comments:

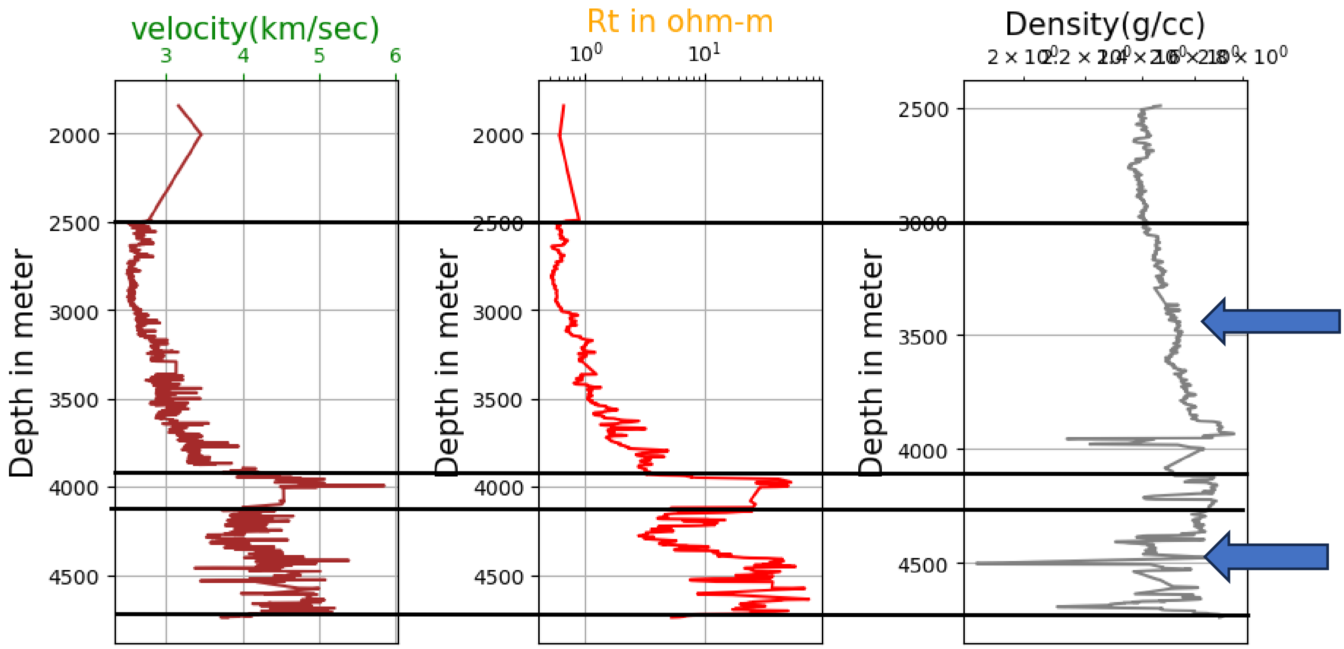
- From the figure 22, I can easily say that density is not much changing but velocity is rapidly dropped.
- Since velocity dropped but there is no large change in density the mechanism should be “unloading”.

Evidance-3: velosity, density and resistivity plot w.r.t. depth.

Unloading condition:

- Velocity in the shale zone need to be decrease with respect to depth.
- Density in the shale /clay zone is not much changing with respect to the depth.
- Resistivity in the shale zone need to be decrease as well with respect to the depth.

If above conditions are matched with the velocity, density and resistivity curves in the shale zone then only I can say with high confidence that the mechanism behind the overpressure arises is “unloading”.



Comments:

- Velocity decreases with depth in the marked zone.
- Density is not much changing with depth in the marked regions.
- Resistivity also decreases with depth in the marked zones.

Conclusion:

To study the above three evidences, I can say with high degree of confidence that my overpressure occurred because of **UNLOADING**.