EXAMPLES TO SHOW THE IMPORTANCE OF USING UPSCALED CORE DATA WHEN COMPARING WITH PETROPHYSICAL DATA

Michael Holmes
Antony Holmes
Dominic Holmes

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ABSTRACT

In many petrophysical studies there is a need to utilize core data, not only to compare with petrophysical results, but also to use as petrophysical input. One example is to combine core porosity measurements with log bulk density in order to derive an appropriate grain density value. Another example, applicable to shale gas reservoirs, is the common practice of using regression analysis by comparing core measurements to logs in order to define a petrophysical model. Often, the comparisons involve no upscaling of the core measurements, which results in less than desirable depth resolution comparisons. It can be readily demonstrated that these comparisons will become more reliable if raw core data is replaced by upscaled core data.

Core measurements are made on samples which are a few cubic inches in volume. Whereas log measurements involve rock volumes of several cubic feet. This discrepancy presents a problem due to the frequent and rapid variations of core data over short vertical distances. Often this variation creates a great deal of "noise" which renders the data difficult to rationalize to the log responses. Upscaled core data give a much better comparison because the "noise" of core variability is often reduced.

In addition to the necessity for upscaling whenever core/log comparisons are made, the technique has an important advantage in that it is much easier to see depth mismatches with upacaled core data than it is by examining raw core data presentation. This is largely due to the fact that the upscaled data appears as a curve over more of the sampled interval, rather than a series of discrete points.

Upscaling algorithms need to account for correct weighting of the data. This is particularly important for anomalous core readings that are not representative of the majority of the data. In the algorithms used in the presented model, upscaling of core data is accomplished by assuming that the average log reading represents three vertical feet of the formation. Running averages are calculated incorporating readings over this vertical range, and giving particular credit to the value at the mid-point.

Examples from a number of reservoirs are presented, comparing raw core data presentation with upscaled core data, while using the same petrophysical curves on both presentations.

INTRODUCTION

Core plug samples are usually about 2 cubic inches (33 cubic cm) in volume. On the other hand, log measurements sample at least a cubic foot (0.03 cubic meter) at a time. The difference in volume measurements, logs to cores is at a minimum close to 1000. For some logging tools with poor vertical resolution and deeper depths of investigation, the difference could be as high as 1,000,000.

Geological heterogeneity would suggest that any core/log comparisons are suspect. It is remarkable that any kind of meaningful comparisons can be achieved. When making comparisons of core data with logs, some form of core upscaling is desirable in order to compare average core measurements over depths that are more comparable to log vertical resolution.

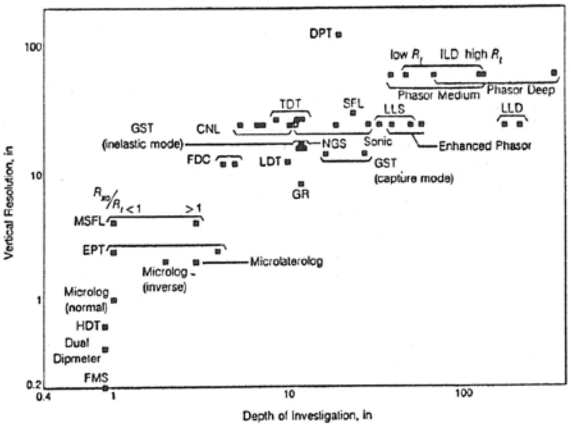

Fig. 1 Vertical resolution of wireline logs, Schlumberger

Log	Vertical ft.	Depth ft.	Volume ft^3
GR	0.75	1	2.36
Density	1	0.5	0.78
Neutron	2	0.75	3.53
Acoustic	2	2	25.13
Laterolog	2	4	100.5
Induction	7	7	1077.56

Table 1 Approximate volumes measured by wireline logs.

GENERAL INSTRUCTIONS

The basic methodology is to "upscale" the core data measurements to the approximate level of the log measurements to improve the correlations between the core and log data. Evaluation of correlation coefficients between the upscaled core data and the log measurements is used to find suggested depth shifts in a rigorous manner. Upscaling is done using a triangular weighted filter, where the midpoint of the triangle in which the main source data resides depth-wise has the most weight for the resulting upscale value. Using this method, the basic character of the core data is maintained, and extended to cover a larger depth interval to match the log measurements.

A larger window for the filter can significantly smooth the core data, eventually rendering it useless at high window values. A window of approximately 1 m (3 ft) is a good approximation of the difference between core data and log data measurements. Observation of many window sizes compared with source log measurements confirms that this is a reasonable size for general use. One benefit of this technique is that anomalously high or low values are still incorporated into the resulting filter data, but their variation from the mean is reduced.

Correlation coefficients mathematically compare two curves to see if they have the same "shape". Positive values indicate a similar shape. Zero values mean there is no correlation whatsoever. A perfect correlation is 1.0. These correlation coefficients are evaluated for the appropriate corresponding log measurement or calculation; for example, core grain density versus log-calculated grain density, or core bulk density versus log-measured bulk density.

APPLICATIONS

It is imperative to try to shift the core data to agree with logs. For sidewall cores, this should not be an issue, however, for continuous coring it is essential. Core depth made by the driller may have discrepancies with log depth – sometimes up to 10 feet or more. For core recoveries of less than 100%, the assumption is frequently made that loss has occurred at the base of the cores as the core barrel is brought to the surface. This might not be a valid assumption as loss could occur by "rubble-izing" incomplete levels at any location on the core. Comparing upscaled core with wireline logs shows very clearly where core shifting needs to happen (**Fig. 2** and **Fig. 3**).

Upscaled core data is very useful when looking at core vs. log cross plot comparisons. On a core vs. log cross plot, upscaled core data will show a tighter correlation than raw core data. This is very useful when looking at a core porosity vs. density log to define matrix density. In general, comparisons of logs to upscaled core show a much tighter correlation than raw core data.

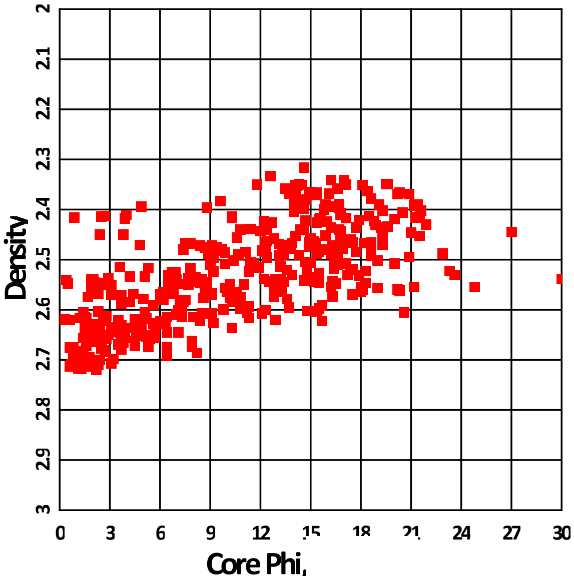

Fig. 4 Core Phi (raw) vs. Density. Calculated matrix density using raw core porosity is 2.658. Example from the Texas Panhandle Brown Dolomite

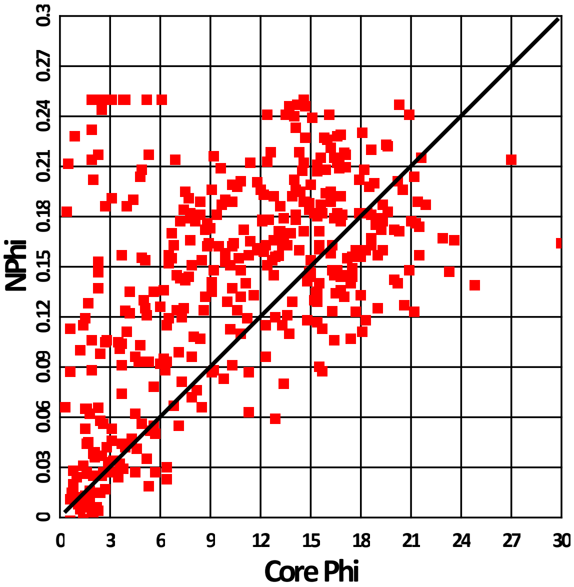

Fig. 6 Core Phi (raw) vs. Neutron. Example from the Texas Panhandle Brown Dolomite.

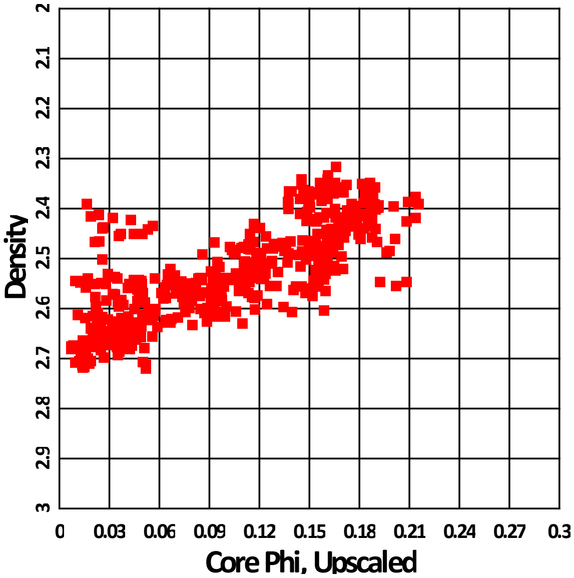

Fig. 5 Core Phi (upscaled) vs. Density. Calculated matrix density using upscaled core porosity is 2.673. Example from the Texas Panhandle Brown Dolomite.

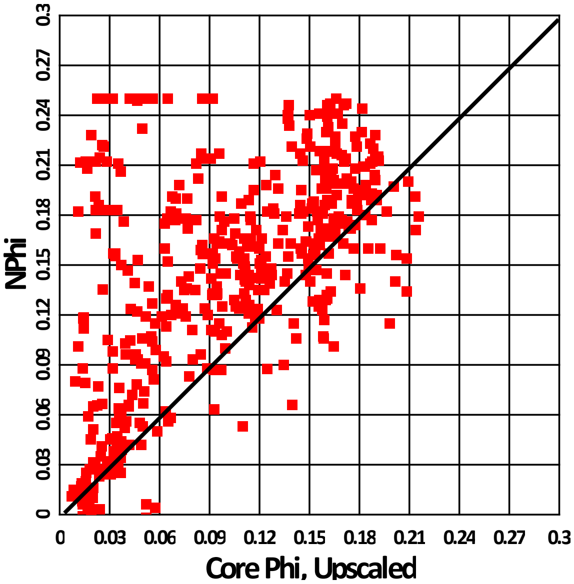

Fig. 7 Core Phi (upscaled) vs. Neutron. Example from the Texas Panhandle Brown Dolomite.

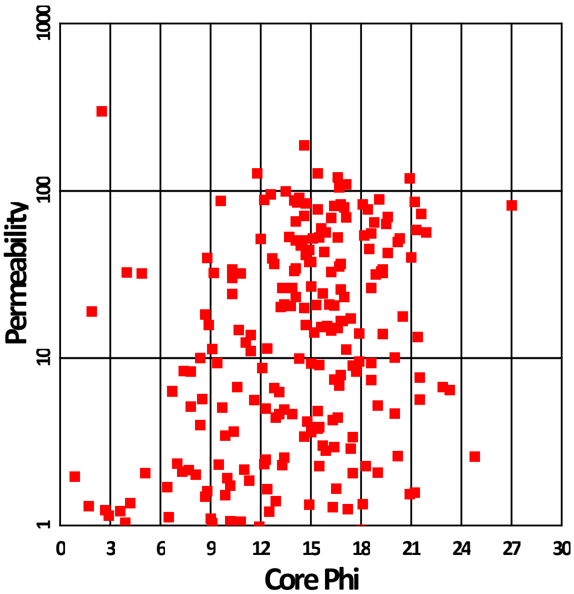

Fig. 8 Core Phi (raw) vs. Permeability. Example from the Texas Panhandle Brown Dolomite.

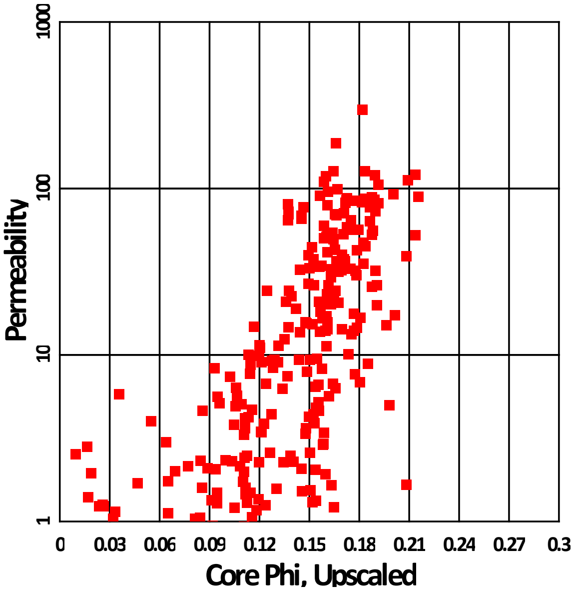

Fig. 9 Core Phi (upscaled) vs. Permeability. Example from the Texas Panhandle Brown Dolomite.

Log calibrations for in-place-hydrocarbons show differences between values of Rho$_{fl}$ and Rho$_{ma}$ when using raw core data or upscaled core data. Two cases were examined for calculations of gross reservoir and net reservoir:

1. Case 1 – raw core data was used to calibrate density log for Rho$_{fl}$ and Rho$_{ma}$ calculations
2. Case 2 – upscaled core data was used to calibrate density log for Rho$_{fl}$ and Rho$_{ma}$ calculations

For both cases, water saturation was calculated using the same m, n, and R$_w$. Shale volume was also calculated identically. The following cut-off parameters were applied in both cases:

- Shale Volume – 25%
- Porosity – 7%
- Water saturation – 50%

Calculated Rho$_{fl}$ using raw core porosity is 1.052. Calculated Rho$_{fl}$ using upscaled core porosity is 1.107. **Fig. 10** shows the differences between raw core data and upscaled core data in calculated density porosity, water saturation, and bulk volume water. **Table 2** summarizes the differences in in-place-hydrocarbon calculations between the two cases.

CONCLUSIONS

Upscaled core data is visually much easier to compare with logs than is raw data. Depth adjustments are more obvious. Upscaling gives a better comparison of core/logs due to a vastly different volume of investigation. Anomalous core data points are smoothed by upscaling, but original data is not lost.

When core data are used to calibrate logs, it is shown that significant difference in calculated in-place hydrocarbon can result. This could be critical in equity studies. Regressions to determine fluid and matrix properties become more meaningful using upscaled data vs. raw data.

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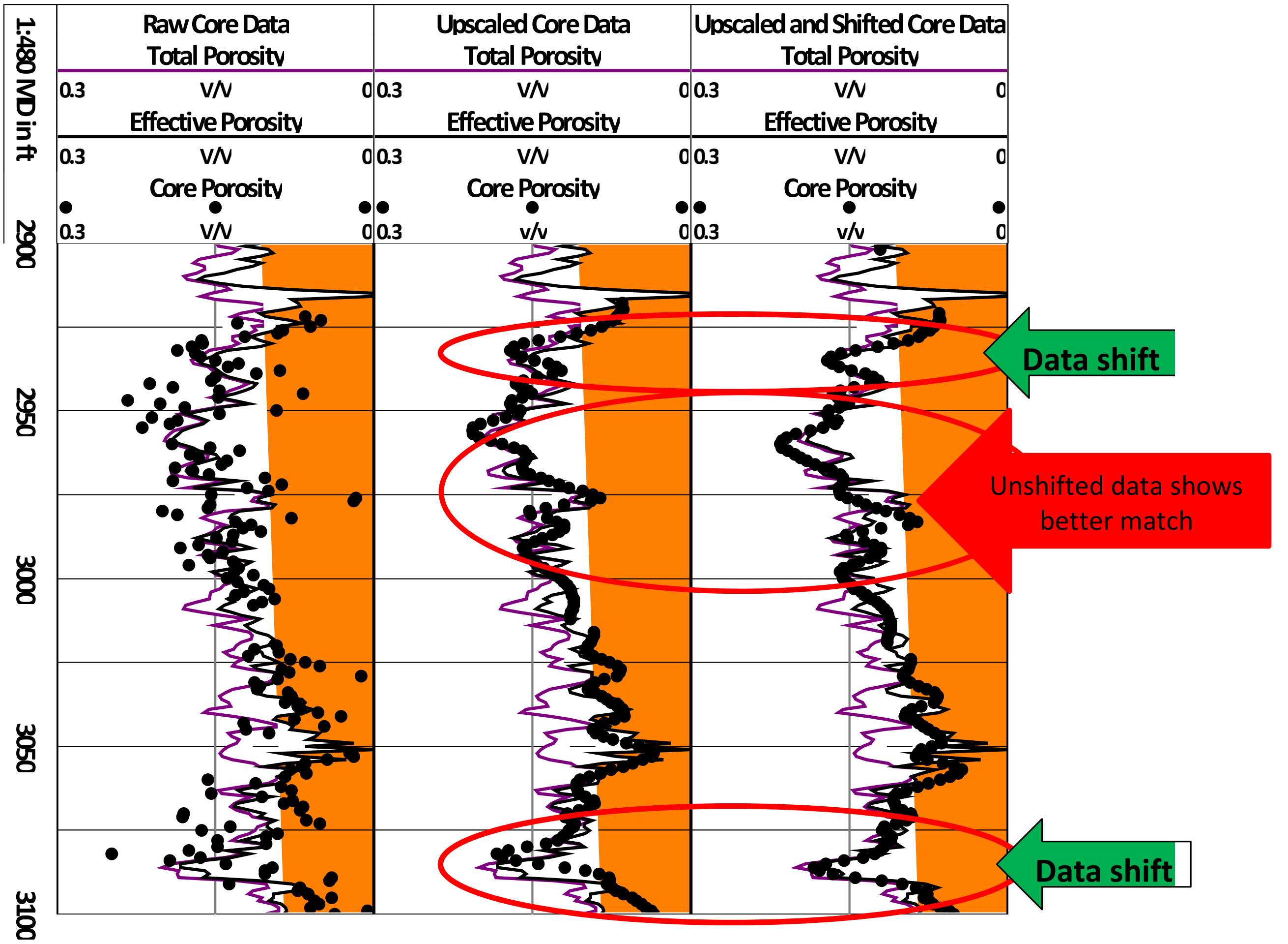
Calculation	Case 1: Raw Core	Case 2: Upscaled Core	Differences	
			Absolute	Percent
Porosity (%)	11.5	12.4	0.9	7.8
Water Saturation (%)	49.5	49.1	0.3	0.6
Net Thickness (%)	228	279	51	22.3
Gas Void Volume (ft.)	13.28	17.71	4.43	33.3
Gas-in-place (MMCF)	12339	16460	4121	33.3

Table 2 Net pay summary comparing Case 1 and Case 2



Data shift

Unshifted data shows better match

Data shift

Fig 2. Illustration of the benefit of using upscaled core data to shift core data. Clearly, it is impossible to discern this shift using raw core data. Example from the Texas Panhandle Brown Dolomite.

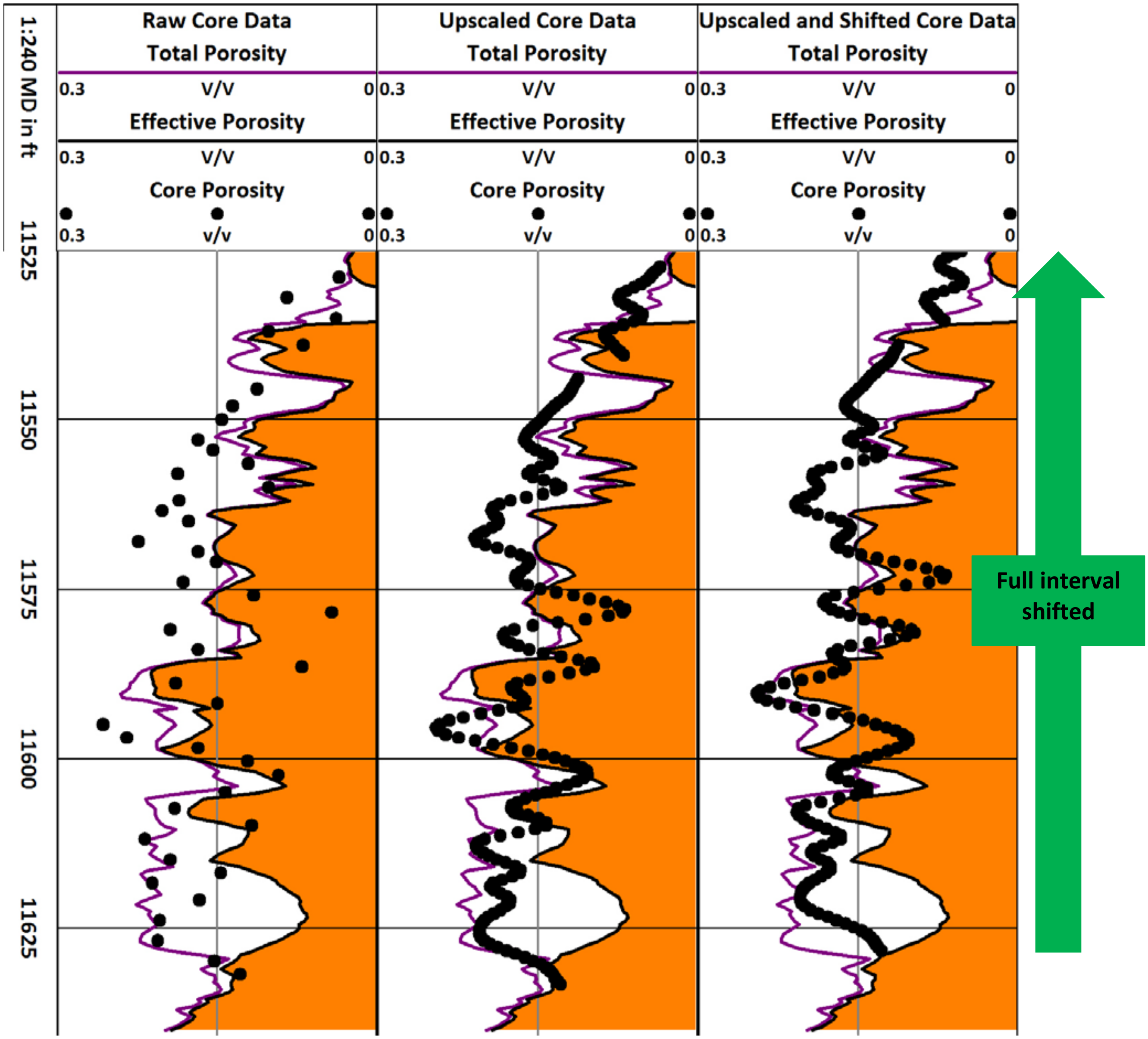


Fig. 3 Entire interval of core has been shifted. Example from Florida.

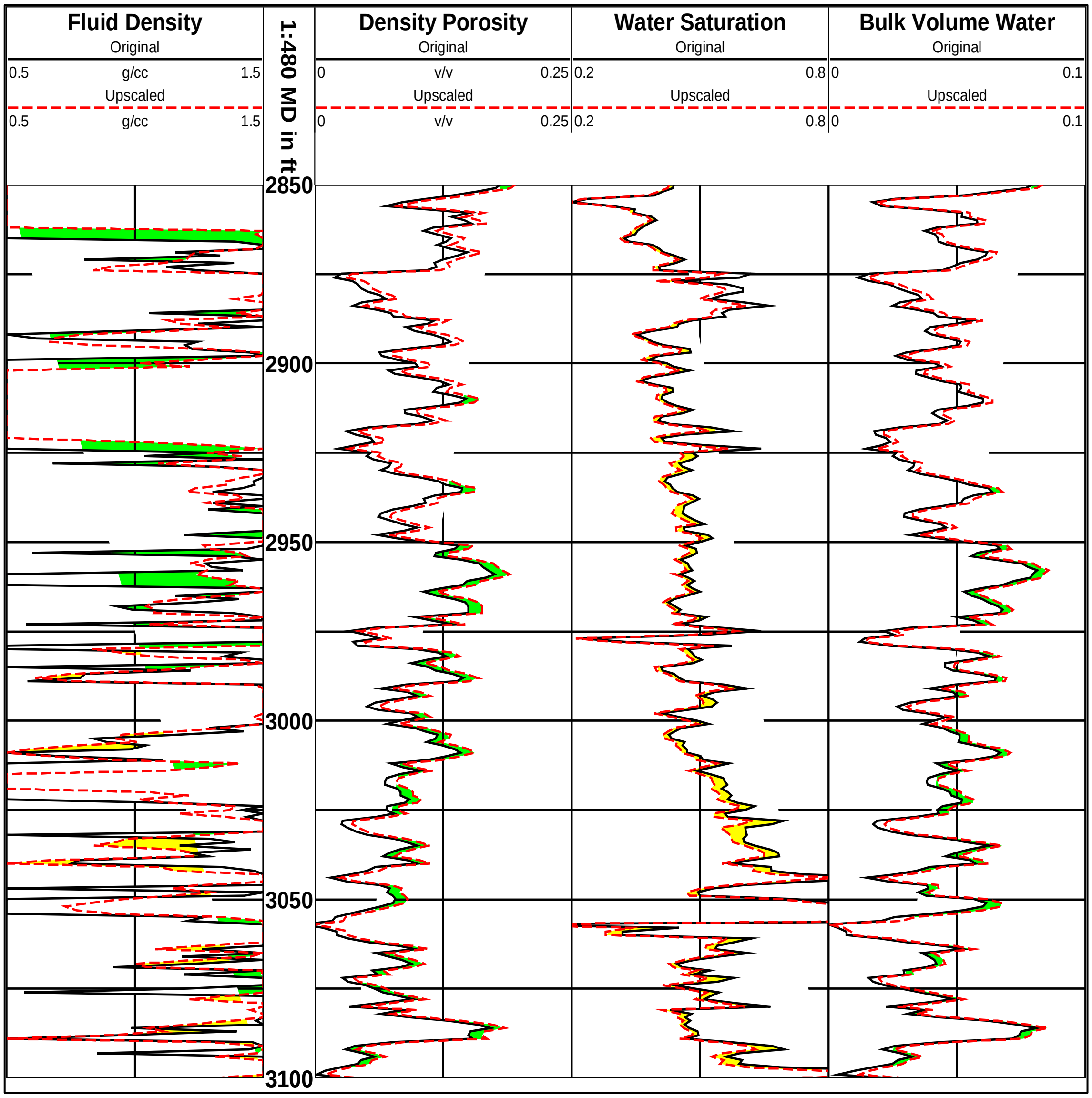


Fig. 10 Differences in calculated fluid density, density porosity, water saturation and bulk volume water when using raw core data and upscaled core data.