Integration of Conventional Petrophysical Interpretation and Borehole Images*

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Search and Discovery Article #41553 (2015)
Posted February 16, 2015

*Adapted from extended abstract prepared in conjunction with a presentation given at CSPG/CSEG/CWLS 2008 GeoConvention, Calgary, AB, Canada, May 12-15, 2008, CSPG/CSEG//CWLS/Datapages © 2015

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Abstract

Crocker Data Processing has worked on improving net to gross and volumetric computations in thin bed reservoirs and has an innovative approach that combines borehole image data and conventional openhole data. A particular problem with openhole image data is the imposition of its character on conventional resolution data produces an answer that whilst close, does not honour the resolution of the conventional data. The approach adopted by Crocker Data Processing involves independent computation of the resistivity, total or effective porosity and Vclay directly from image data, calibrating these results against openhole data. The results produce both independent image log based petrophysical volumes as well as input that is high resolution and can be used in a deterministic petrophysical model. This resolution improvement allows heterogeneous thin bed reservoirs to have better volumetric parameters produced for incorporation in reservoir modelling and reserves calculation.

Introduction

Conventional petrophysics such as the silty shaley sand model and applying Thomas-Steiber techniques to understand heterolithic reservoirs usually provides a fair answer where you have thin bedded or heterolithic reservoirs. This technique however is limited by the resolution of conventional log and leaves such questions as whether the saturation, porosity and hydrocarbon distribution is correct. Other things such as the computation of permeability are quite hazardous when applying a generic log-linear function or indeed one of the other functions to the porosity to estimate permeability.

Image log data has been used in a crude manner to calculate volumetrics in these intervals by simple conductance based cutoffs that rely on sand being more conductive and shale being less conductive. We intend to demonstrate in this paper that by using the conductance distribution inherent in the acquired conductivity based resistivity imagers we can obtain textural information and a much better idea of the volumetrics within such heterolithic intervals. We also show that by using this information, relative grain size distributions that have a constant porosity will affect the computation of permeability and identification of potentially producible hydrocarbon.

Method and Results

Initial work was based on a standard set of wireline logs with an average 0.6 M (2ft) resolution. Log analysis worked well in thicker sand packages and matched core porosity. Permeability from the core showed two distinct porosity vs. permeability trends. Between sand packages with the same effective porosity, the permeability was vastly different.

Nuclear Magnetic Resonance (CMR) acquired over the sand interval showed the same computed similar volume of clay (Vclay) and effective porosity but at a higher resolution (6”). What is clearly visible from this additional data is the pore size distribution. The sand package with the higher permeability has a significant portion of large pore size that is not present in the lower permeability sand. Permeability computed is a close fit with the core data.

Where these tools often fail to provide a correct result is in thin laminated sections where the tools read an average over a laminated interval. Interpretation resulted in a mid quality dirty formation with low effective porosity and a directly related higher formation water saturation. Any zone such as that shown in Figure 1 can be questioned. It is important to consider if a zone could be laminated.

The image log data acquired over the reservoir interval shows reasonable variation that is implied to represent the sedimentary and structural features in the reservoir examined by petrophysics (Figure 2). Comparison with core through the interval shows similar information can be taken from the images and representative of the sedimentary structure within the reservoir.

The technique we apply calculates a whole range of parameters directly from the images and these include porosity (effective and total), permeability, a textural mean, a heterogeneity index, and volumetric fractions of silt, sand, shale and fluid. In addition distributions of conductivity, porosity and texture are also computed (Newberry et al. 2004). The saturation and porosity from conventional petrophysics are used to guide the image petrophysical computation. It does not change or influence the resolution (1.2”) of the data in any way.

Figure 3 illustrates the computation of the various distributions using the image petrophysics developed in PETROLOG. The textural spectrum is computed by normalising the part of the spectrum considered to relate to the grain structure in the rock.

The textural analysis computed for the same interval as shown in Figure 2 is illustrated in Figure 4. The analysis of the openhole logs as discussed earlier is compared with the high-resolution volumetric analysis and grain size distribution. The image petrophysics highlighted that the interval in question is indeed heterolithic. Based on the images alone beds of different conductivity can be observed. The results show the textural map distribution (Track 5) correlating with the intervals of more clay and less clay. More clay is on left and less clay is on the right. The sand rich cycles range from five to 10 cm approximately in size and range from predominantly clay or silt particle size up to medium to coarse grain size for the sand. Track 6 illustrates the heterogeneity or broadly speaking a sorting index and the red peaks to right indicate good sorting whilst the low parts illustrate poor sorting. In general, the sands show poor sorting around a fine to medium grain size and occasional coarse grain size.

The image petrophysics calculates volumetrics and when compared with the openhole volumetrics (Tracks 7 and 8) we find that the openhole logs average the response significantly. The computed volumetrics from the image petrophysics reflect better the structure of the interval. The results from the image petrophysics can be directly used to compute volumes of hydrocarbon and in this case illustrate where potentially the hydrocarbon within the interval is distributed.

As a nuclear magnetic resonance tool (CMR) was run over this interval, we elected to compare the average T2 distribution with the textural mean. Both distributions in some way are reflective of pore throat size and therefore some correlation should be apparent if we are really seeing the pore throat distribution (Coates et al 1999) or inferred grain size distribution. Illustrated in a cross-plot of average relaxation time versus the textural mean computed from the image data (Figure 5) we observe a reasonably consistent relationship. The spread at 100 MS shows that the interval pore throat size within the sands in changing which impacts on permeability yet porosity is staying constant. This more or less constant average value for the T2 average relaxation time is interpreted as a function of CMR resolution. A further step not yet investigated would be to consider this information in a permeability computation.

Conclusions

The use of conventional logs alone will allow gross quantification of the hydrocarbons, lithology and pore volumes within heterolithic intervals. In heterolithic intervals, we find that the distribution of porosity and various sand types can be precisely determined using the Image Petrophysics approach. It permits currently, computation of high-resolution volumetric curves and distribution of not only sand and shale but also division of the sand into various textural components that are inferred to represent pore size or grain size distribution and sorting.

Acknowledgments

We acknowledge and thank Crocker Data Processing Pty Ltd for permission to publish this work.

References Cited

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Newberry, B.M., S.M. Hansen, and T.T. Perrett, 2004, A Method for Analyzing Textural Changes within Clastic Environments Utilizing Electrical Borehole Images: GCAGS Transactions, v. 54, p. 531-539.

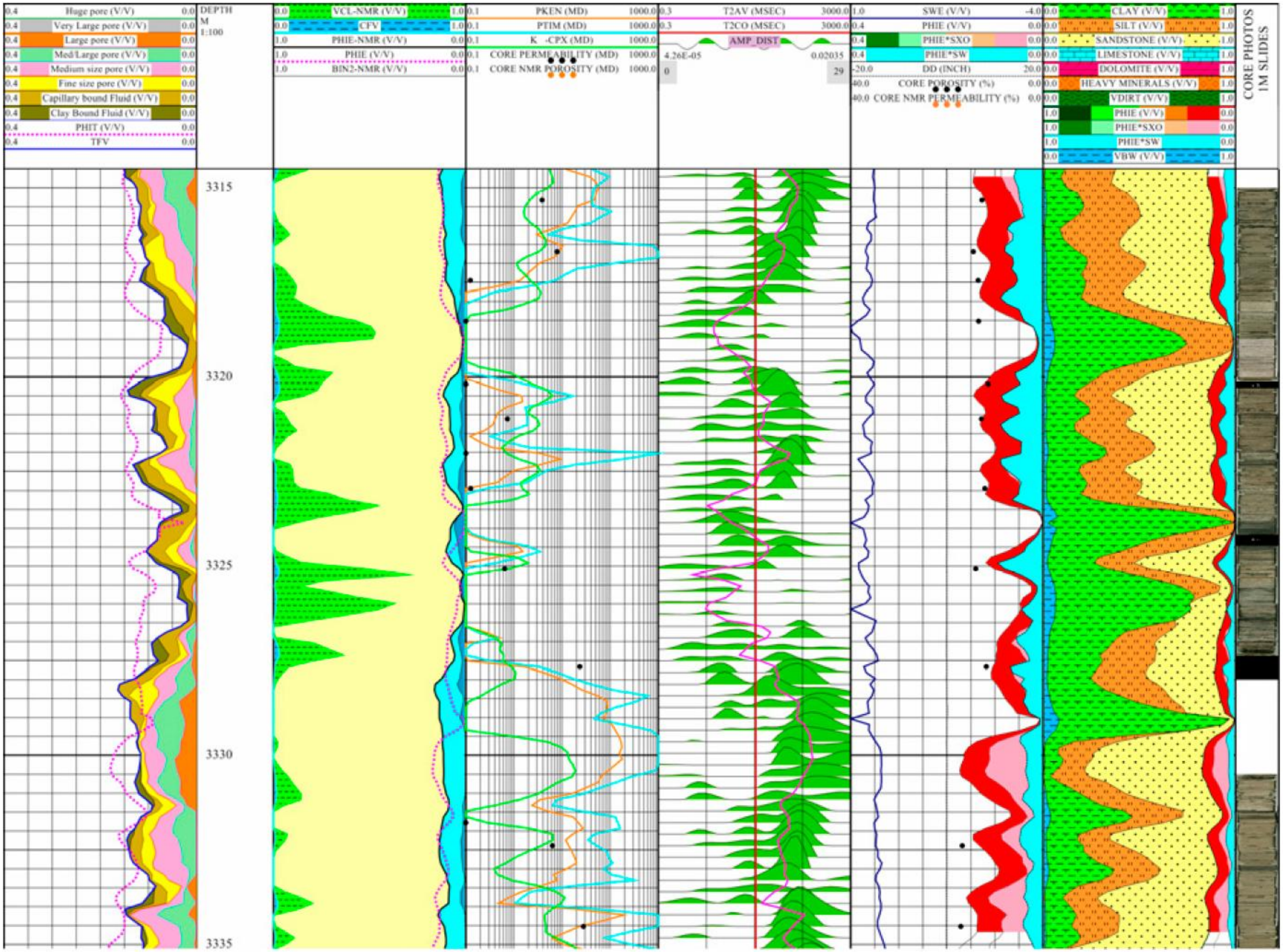

Figure 1. Comparison of CMR vs. Wireline log analysis vs. core analysis with core photos.

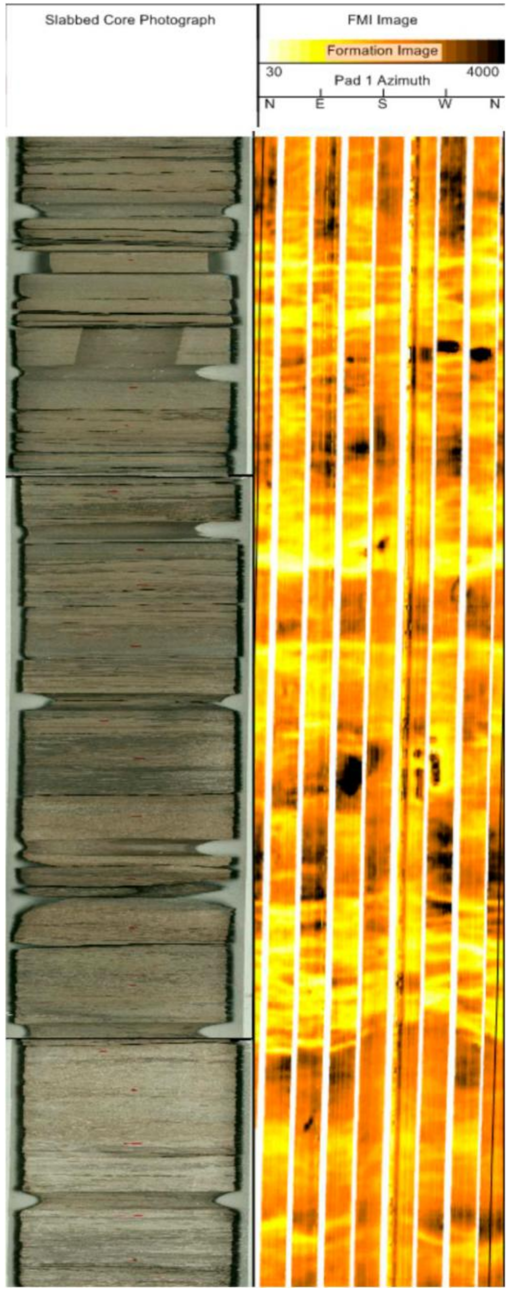

Figure 2. Comparison of core vs. image log for approximately 1.1 M of core.

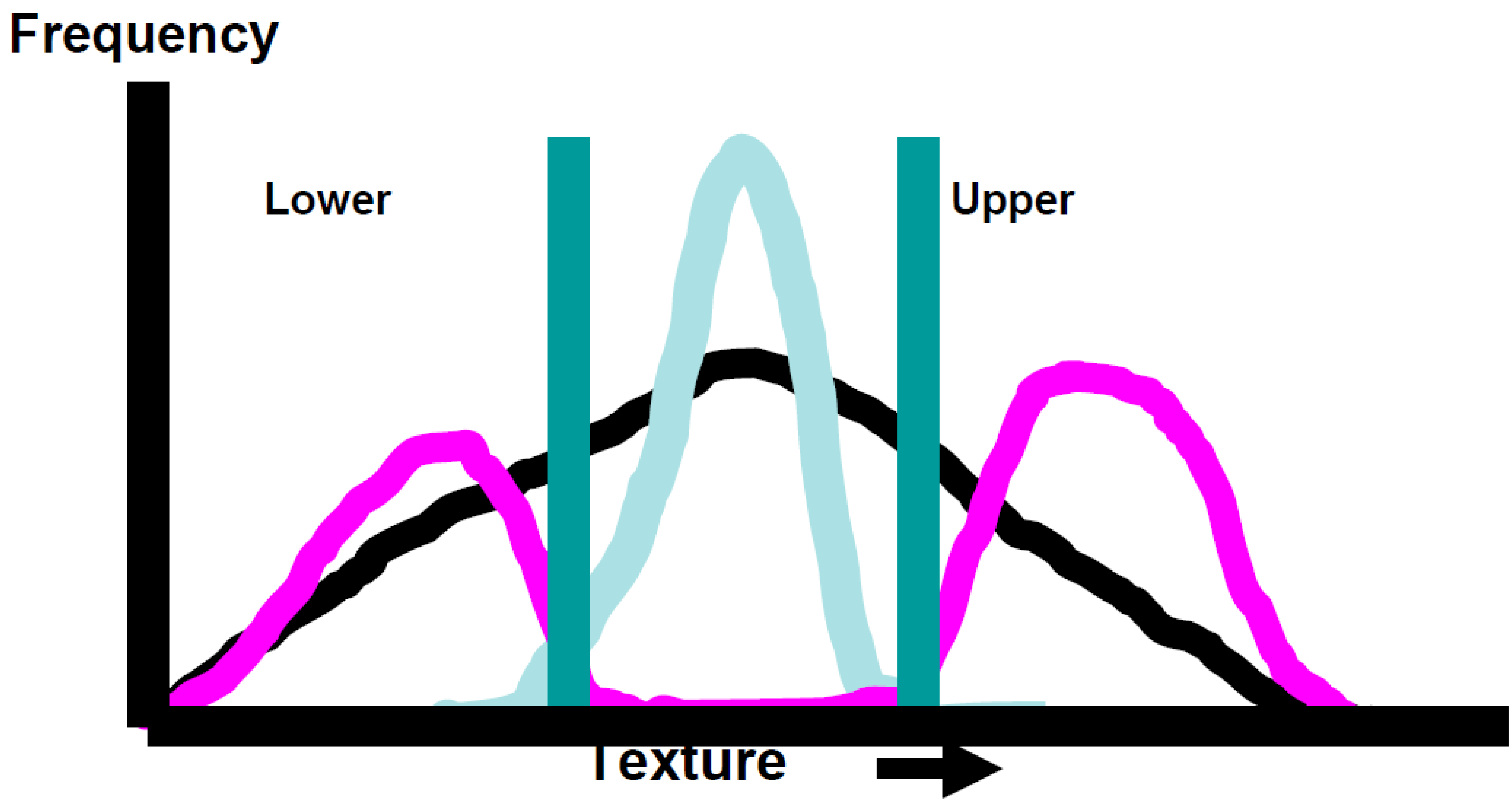

Figure 3. After locating the peak of the receptivity distribution, it is possible to set boundaries that define the extent of a textural distribution. Points falling outside the boundaries can then be examined independently.

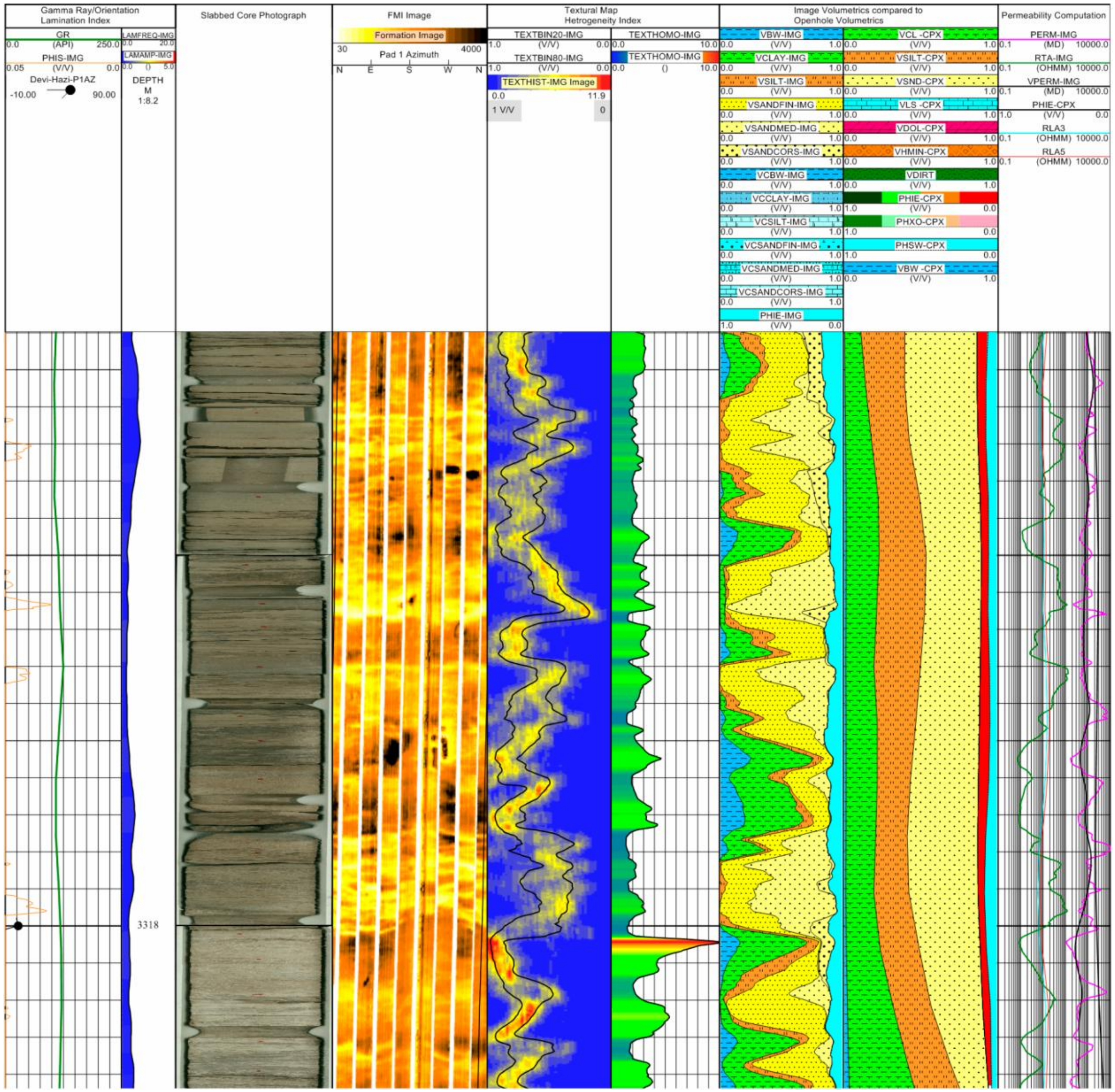

Figure 4. Comparison of core vs. image log for the same interval as Figure 2. See text for detail. Tracks 1 and 2 are Gamma Ray, orientation and lamination index, and depth. Track 3 is core photograph. Track 4 is FMI image, Track 5 and 6 are textural distribution and heterogeneity. Track 7 and 8 are high-resolution image petrophysics volumetrics and conventional resolution petrophysics respectively. Track 9 is permeability and high resolution true resistivity.

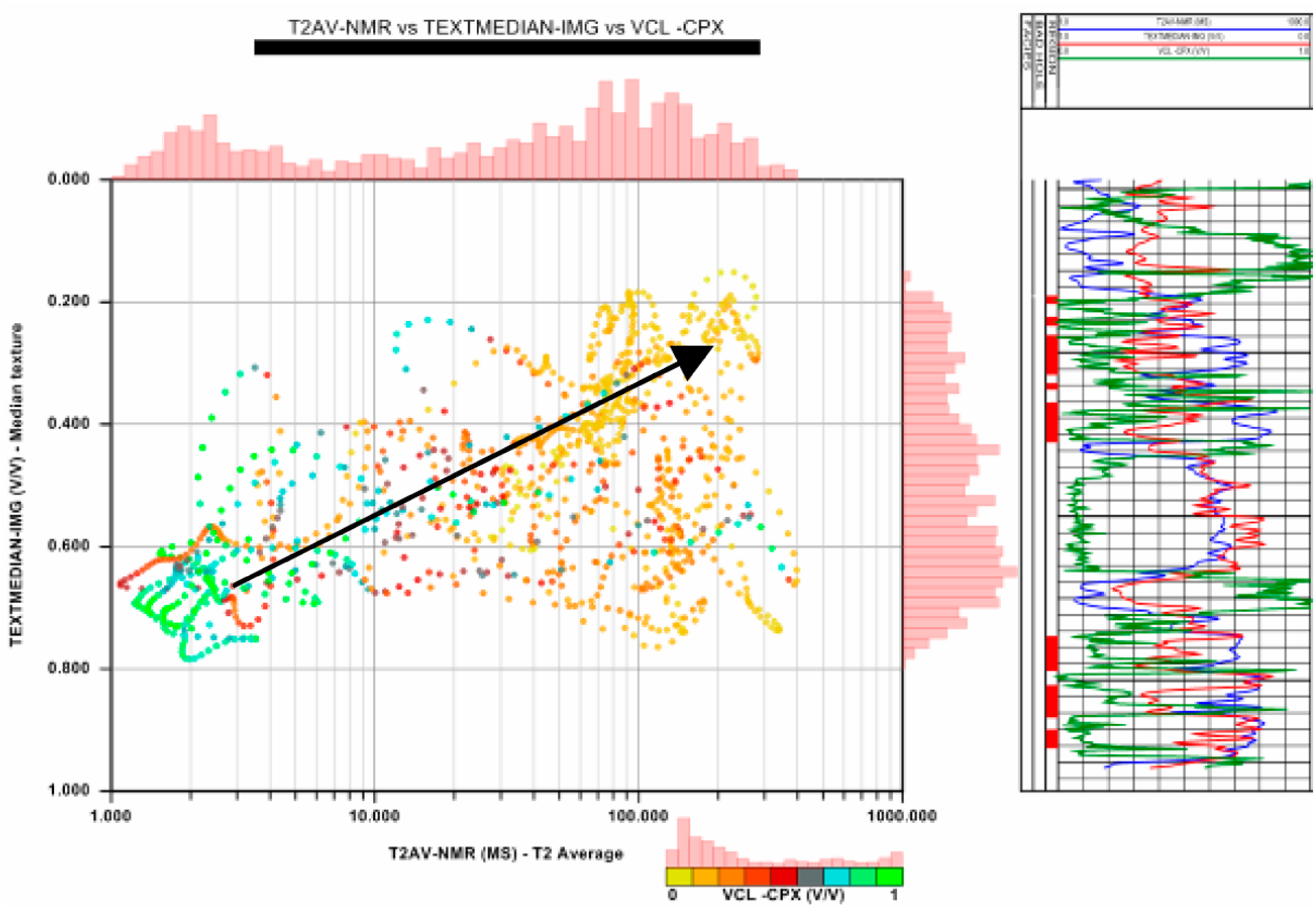

Figure 5. When cross-plotted the textural mean and Average T2 relaxation time give a trend that shows increasing pore throat size or inferred grain size that correlates. The spread towards 100 MS. This shows that the textural mean is seeing the variation in pore throat size that relates to grain size variance in the sand fraction and the NMR is somewhat insensitive to it.