Visual Analytics: The RGB Co-Render – What Are We Going To Do With the Answer?*

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Abstract

Because two seismic attributes – amplitude and phase – are required to build signal on a seismic trace, any single seismic attribute derived from a recorded seismic wave field simply cannot carry all available discrimination. Thus, only analysis of multiple attributes can address most – instead of few – aspects of subsurface geology. To rapidly discern either which suite of attributes or which part of their dynamic range proves prognostic, interpreters have gained access to statistically-driven data mining routines, such as multivariate statistics, principal component analyses, and supervised or unsupervised neural network classifications. In spite of these quantitative, largely automated data reduction techniques, qualitative interpretation remains of great merit. However, to be able to effectively compete against automated data mining routines, manual interpretation of attribute data must be subjected to the challenge of simultaneously illuminating key reservoir characteristics.

Discussion

One such visualization technique, RGB co-rendering (Figure 1), has traditionally been applied to spectral frequency decompositions of amplitude data. Here, RGB visualization of multiple amplitude volumes centered at discrete Fourier frequencies offers many benefits to an interpreter, one of which is to unmask hidden details of seismic stratigraphy away from the dominant frequency of PSTM amplitude data. In keeping with this traditional RGB usage, we firstly present an example of a partially breached Tertiary petroleum system in the northern Gulf of Mexico, wherein frequency spectral decomposition of amplitude data effectively serves to separate late-stage, non-sealing, planar (steep) faults from less steeply dipping, syndepositional listric faults.

In addition to RGB visualization of relative data (i.e., amplitude data conforming to a Gaussian normal distribution centered at a zero mean), we present solution-driven RGB co-render visualizations to query elastic inversion seismic data from conventional and unconventional reservoirs. However, rather than selecting attributes based on, for instance, statistical rank, three (or more) choice attributes are recommended by the human interpreter to be matched up in visual response to answering a geological question. To ascertain that the objective stated by the geological question is actually achieved during RGB visualization, select key components of the reservoir have to be visually calibrated against physical parameters of the reservoir rock as seismically expressed in elastic inversion attributes. Therefore, after having defined governing reservoir criteria, we selectively block the non-prognostic dynamic attribute range via opacity controls and/or color. Ably, rock physics-based definition of thresholds or cut-offs in the attribute data is obtained by calibration of seismic inversion data to up-scaled, well logs of elastic attributes during bivariate analyses. Where all required reservoir conditions have been successfully met, white emerges as the composite color (Figure 1). Should the visual attempt at combining elastic attributes in RGB mode prove useful to the interpreter, sequential volume multiplication using binary [0,1] decision-tree discrimination can subsequently be applied to further data mining efforts (Figure 2). Thus, geobodies for which all three (or more) specified conditions have been met can be used to obtain, for instance, volumetric estimates.

Results

Three such reservoir characterizations using elastic inversion data are presented in RGB-mode. In the first example from a Tertiary deep-water turbidite sandstone setting, we additionally feature a three-phased workflow to progressively filter 3-D seismic data through calibration to rock physics reservoir parameters, thus distilling desired "sweet spots." We incorporate producing reservoir characteristics in RGB mode to 1) detect sand; 2) assess reservoir quality; and 3) predict fluid fill. In another example, we briefly demonstrate how RGB stacking of geobodies from different stratigraphic depth intervals can be used to highlight overlapping pay zones for purposes of optimizing a single well bore location. In a final example, we pioneer a workflow wherein multiple seismic attributes serve to potentially separate open from closed faults. To accomplish this goal we analyze Kohonen self-organizing map weights (Figure 3) from unsupervised neural network runs of multi-trace, first and second-derivative curvature and similarity seismic attributes to detect fault facies. The results from this workflow become co-rendered with a (fracture) porosity cube and an elastic attribute that portrays shear wave slowness due to fracturing.

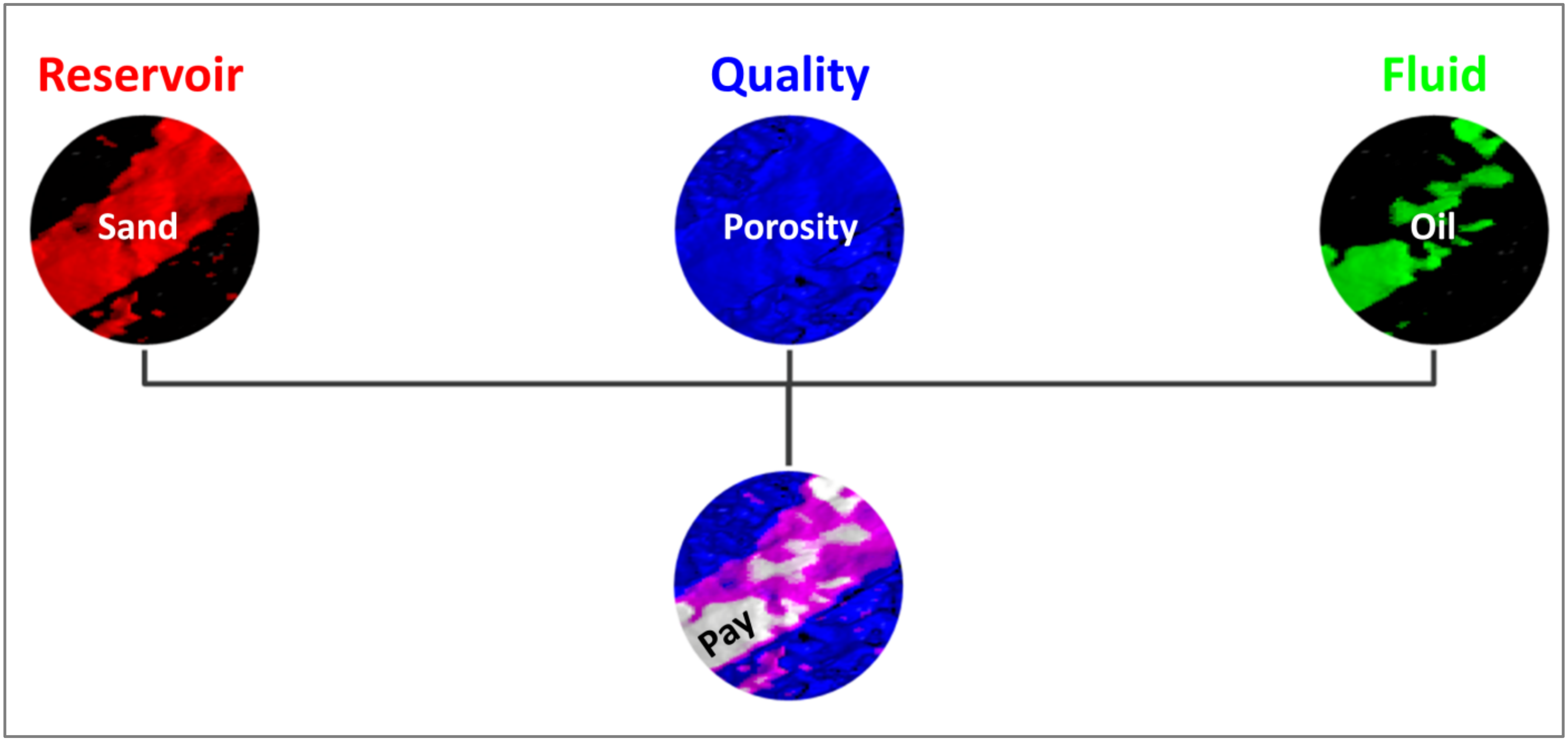

Figure 1. RGB co-rendered display of elastic attributes. Elastic attributes calibrated to thresholds or cut-offs grounded in rock physics permit the interpreter to detect distribution of reservoir sands, assess reservoir quality via porosity estimates, and predict fluid fill from statistical rock physics templates. In the figure above, red gives only sand (threshold in relational attribute); blue gives total porosity (threshold determined from rock physics); green gives hydrocarbon charge (cutoff determined from rock physics). Where all three reservoir conditions are met favorably, white emerges as composite color.

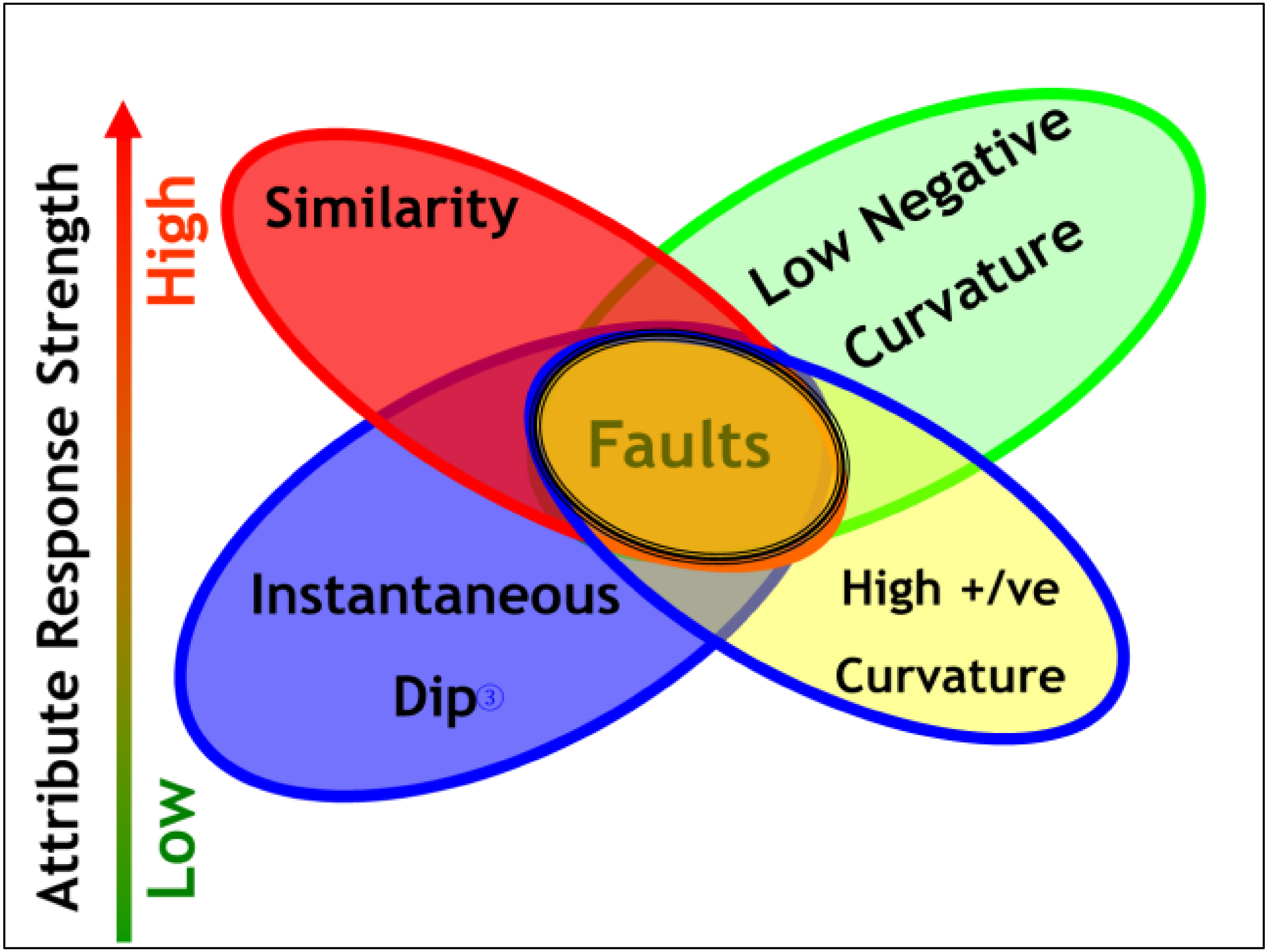

Figure 2. Fault detection by multiple attributes. Since faults are found at greater probability in Boolean multitude intersections of certain post-stack seismic attributes, an artificial neural network is employed (LITHANN®) to help facilitate fault detection. Geological rationale dictates that major faults will be associated with values of low similarity, high (i.e., steep) instantaneous dips, and extreme curvatures.

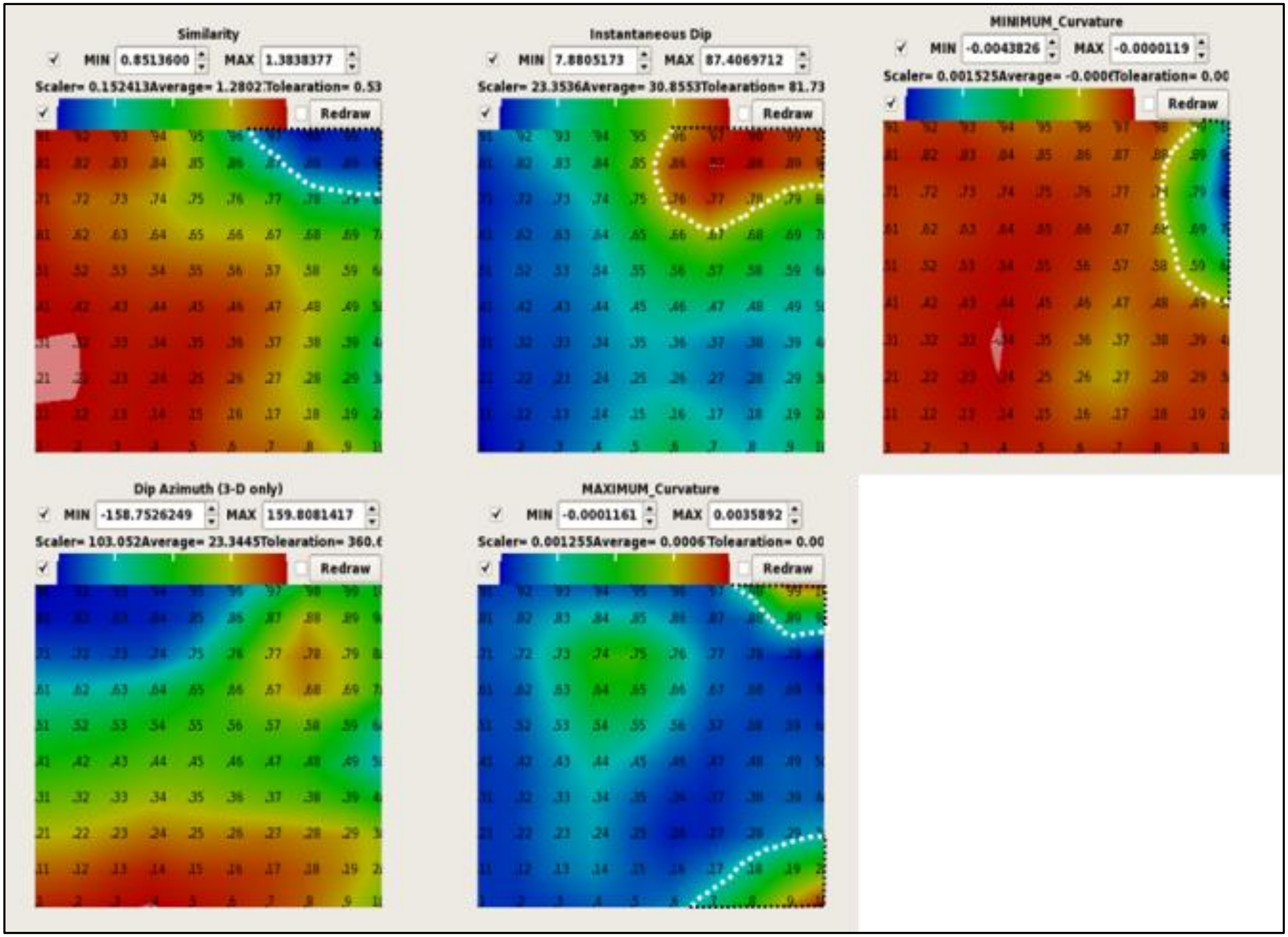

Figure 3. Kohonen Weight Maps. Different map patterns of multi-trace first- and second-order derivative seismic data support the notion that independent information not contained by a single attribute can be gleaned from multiple attribute analysis. Subsequently, observed gradient changes in each attribute are interpreted as reflecting the rapid physical break of going from faulted to unfaulted seismic volume (demarcated by dashed white lines).