geoconvention
Virtual Event September 13 - 15 2021

The Value of Pulsed Neutron Geochemical Logging Tools in Geomechanical Characterization of Unconventionals

Rachel M Ospina, Claudia M Amorocho
Weatherford International

Summary

Detailed formation mineralogy from geochemical logging tools has become very important for the accurate evaluation of subsurface reservoirs. The measurement of mineralogical content, in addition to elemental concentrations on which the mineralogy is based, goes beyond providing significant assistance in the determination of reservoir properties, such as improved grain density and porosity. The mineral characterization also provides useful information related to hydrocarbon saturations and rock mechanical properties with critical implications to field development assessment and operations.

For the particular case of geomechanics, the rock fabric has a direct impact on rock mechanical properties such as Young's modulus, Poisson's ratio, unconfined compressive strength, intrinsic rock anisotropy, ductility, among others. A mineral like quartz will have a different impact as a cement than as discreet grains. In turn, these parameters will make a difference in the way the formation reacts to subsurface operations including drilling, stimulation and production. Proper characterization of mineral content allows for better understanding and quantification of geomechanical parameters and then, a timely identification of potential challenges in oil and gas extraction activities.

Theory / Method / Workflow

The use of a new pulsed neutron geochemical tool, including a state-of-the-art LaBr3 detector system with fast electronics and a pulsed neutron generator (PNG), allowed for the detailed mineral characterization of hydrocarbon bearing formations. In addition to petrophysical characterization, a quantification of geomechanical properties using detailed mineral analysis was performed.

The PNG in the spectroscopy tool emits high energy 14 MeV neutrons that interact inelastically with elements in the surrounding formation, resulting in the identification of carbon, aluminum, and magnesium, as well as other elements. The resulting thermal neutrons, after being captured by atomic nuclei, allow the identification of additional elements, among them being calcium, silicon, sulfur, iron, and titanium. Using a deterministic process based on element-mineral relationships, mineral composition and quantities are derived from these elements. These results are used as input into various models for improved assessment of the reservoir.

Detailed mineralogy analysis was used to determine relationships between acoustic velocities and specific mineral composition, formation porosity and fluid saturations. Figure 1 displays the mineralogy, petrophysical, and acoustic properties. Acoustic velocities and dynamic rock mechanical properties were used as a baseline since these correspond to the traditional industry methods for calculation of geomechanical parameters. Trends were assessed between minerals and physical rock properties as shown in Figures 2 – 7. Forward modeling was used to estimate the compressional slowness from the mineralogy and fluid saturation and compared with the acoustic measurement in Figure 8.

Characterization of intrinsic anisotropy (vertical transverse anisotropy, VTI), critical in the behavior of rock mechanical properties in organic shales, was estimated in formations where it was expected and correlated to specific minerals; a clear effect of minerals such as illite and calcite and can be observed in Figures 9 and 10.

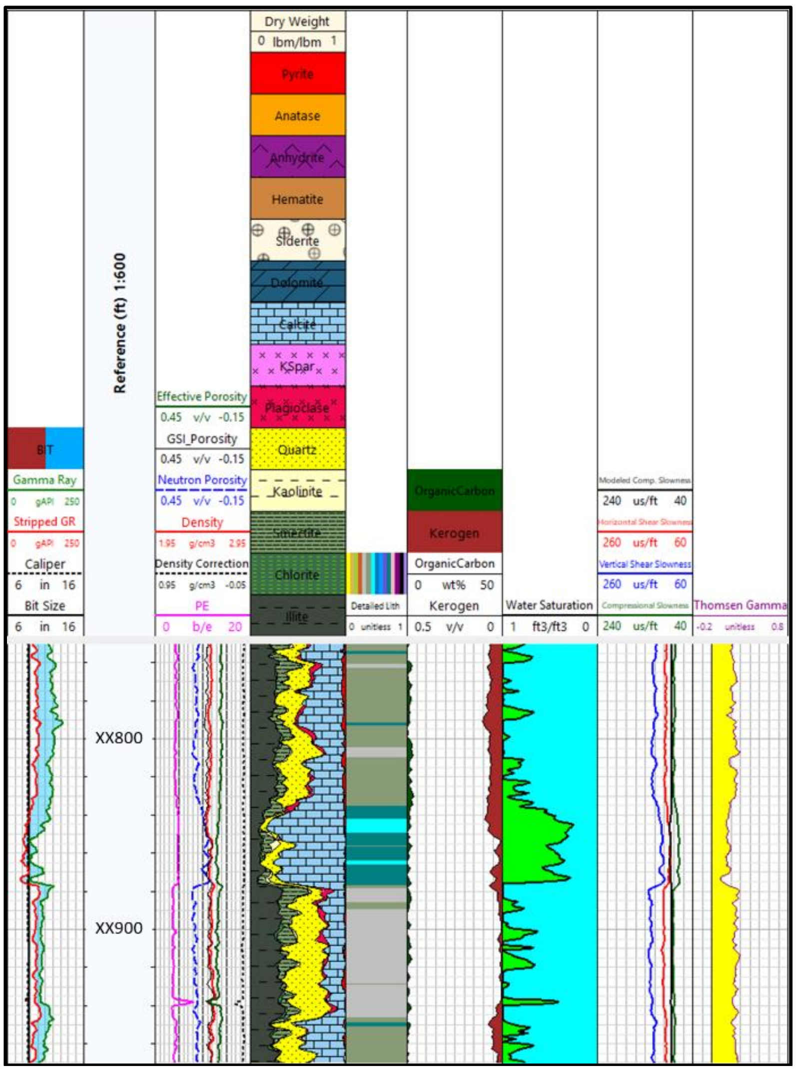


Figure 1 – Mineralogy, petrophysical and acoustic properties plot.

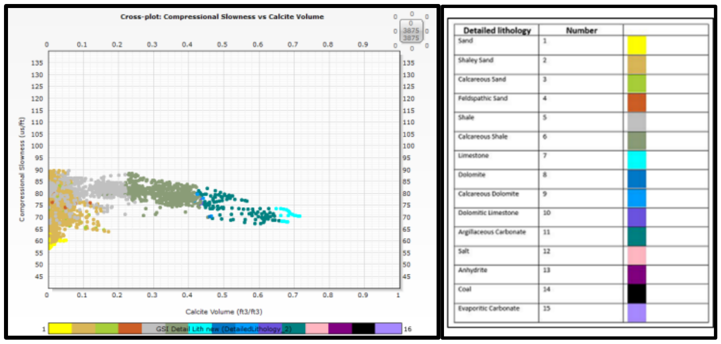


Figure 2. Compressional Slowness vs Calcite Volume with dominant lithology shading showing the trend of compressional slowness decreasing with increasing calcite volume.

a) b)

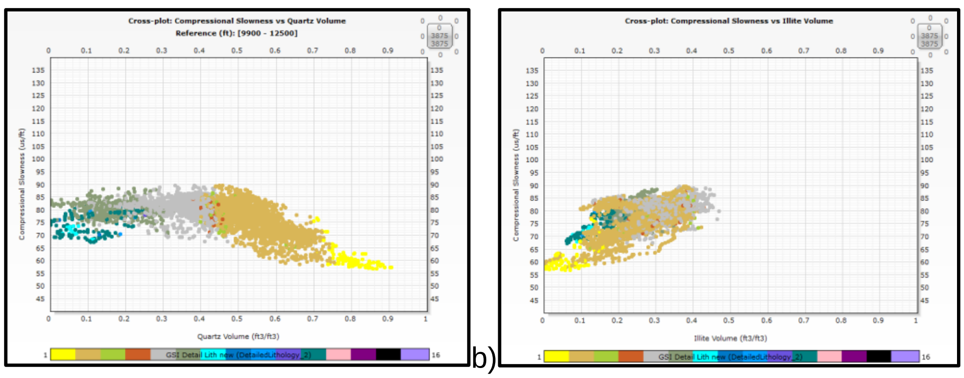


Figure 3. a) Compressional Slowness versus Quartz Volume with dominant lithology shading showing an increasing trend in slowness in shales and a decreasing trend in cleaner sands. b) Compressional Slowness versus Illite Volume shaded by dominant lithology showing an increasing trend in slowness with increasing illite volume.

a) b) c)

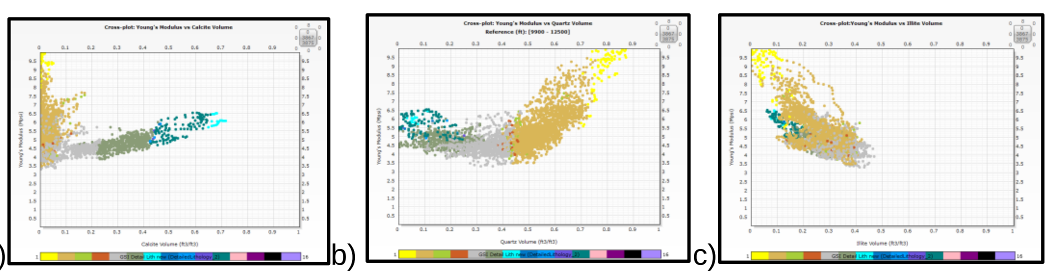


Figure 4. a) Young's Modulus versus Calcite Volume shaded by dominant lithology depicting an increasing trend in young's modulus with an increase in calcite volume.
b) Young's Modulus vs Quartz Volume shaded by dominant lithology depicting young's modulus varying as a function of quartz volume dependent on the lithology.
c) Young's Modulus versus Illite Volume shaded by dominant lithology depicting a decreasing trend in Young's modulus with increasing volume of Illite.

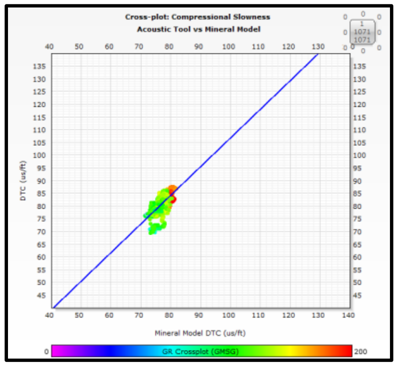


Figure 5. Acoustic Compressional Slowness versus Mineral Model Compressional Slowness depicting a reasonable estimation of compressional slowness based on the mineral model.

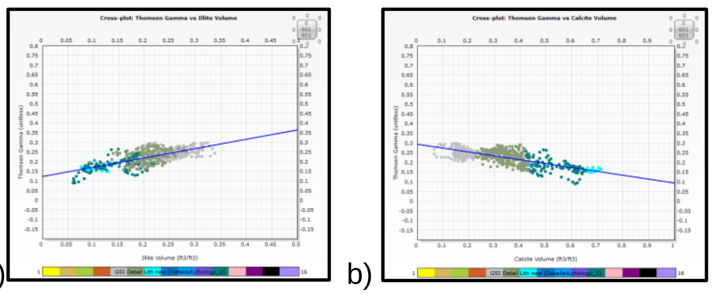
a) 

Figure 6. a) Thomsen Gamma versus Illite Volume depicting an increasing trend in VTI anisotropy with increasing volume of illite. b) Thomsen Gamma versus Calcite Volume depicting a decreasing trend in VTI anisotropy with increasing volume of calcite.

Results, Observations, Conclusions

The detailed mineralogy from the geochemical logging tool, as well as its correlation with other logging measurements, is thoroughly analyzed. The mineralogical and petrophysical characterization from measurements taken by the pulsed neutron geochemistry tools and other log measurement were compared along several varying lithology sections in order to stablish the correlation between specific mineral occurrence with other readings. Minerals including Illite, Calcite, and Quartz were correlated with acoustic velocities, proving the need for detailed mineralogy in order to properly quantify rock mechanical properties from petrophysical characterization. Further analysis could also include the effect of specific minerals on the occurrence of features such as changes in rock texture and natural fractures.

Novel/Additive Information

This paper presents data from a new geochemical spectroscopy tool and, in addition to the traditional applications of elemental and mineral data, offers new approaches to integrating spectroscopy data with other logs for advanced reservoir evaluation and rock mechanical properties. By incorporating mineralogy and improved grain density in complex reservoirs, the porosity is better understood, and can serve as a critical parameter for rock quality estimation.

References

1) Pemper, Richard , Pereira, Alex , Hou, Guojing , Dolliver, Darrell , Tudge, Joanne , Kharrazi, Jennifer , Chok, Hamed , Schmid, Gregory , Mekic, Natasa , Blankinship, Tom , Epstein, Robert , Cave, Tim , and Adam MacPherson. "A New Geochemical Logging Tool for Determination of Formation Chemistry and Mineralogy in both Conventional and Unconventional Reservoirs." Paper presented at the SPE Annual Technical Conference and Exhibition, Dallas, Texas, USA, September 2018. doi: https://doi.org/10.2118/191411-MS
2) Mavko, Gary, Tapan Mukerji, and Jack Dvorkin. The Rock Physics Handbook: Tools for Seismic Analysis of Porous Media. Cambridge, UK: Cambridge University Press, 2009.