

CLAY MINERAL ANALYSIS OF THE VACA MUERTA-QUINTUCO SHALE SYSTEM, NORTHERN NEUQUÉN BASIN, ARGENTINA

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Neuquén basin represents the most productive gas basin in Argentina, while the VacaMuerta-Quintuco system (Tithonian-Valanginian) is considered as one of the most important unconventional plays in the world. In order to increase productivity and predict their rheological behavior, detailed mineralogical analysis is essential on these plays. This contribution allowed us to make a detailed characterization of the transition from a carbonate ramp (VacaMuerta Fm) to a mixed siliciclastic-carbonate shelf (Quintuco Fm). The analysis of clay minerals revealed a high-ordered illitic material dominated shale, with variable contribution of Fe-rich chlorite. The smectite-illite interlayers (I/S) of marlstones revealed a high ordering (R3), while the I/S of other lithologies showed a subtle increase in expandibility, suggesting a different diagenetic process.

In the outcrops of PuertaCuraco (Northern Neuquén Province), the VacaMuerta Fm is ~400 m thick and consists of rhythmic alternations of marlstones and limestones, with interbedded 0.5-50 cm thick volcanoclastic layers (tuffs). Overlying VacaMuerta Fm, Quintuco Fm (~300 m) consists of limestones, shales and fine-grained sandstones, indicating a shallowing upward sedimentary cycle. The amount of clay minerals increases upward along the entire system while the carbonate content (calcite and dolomite) decreases (Kietzmann *et al.*, 2016).

Systematic sampling and mineralogical analysis (XRD) were performed on the entire sequence (~700 m) in order to study the paleoenvironmental transition through the carbonate ramp to the mixed siliciclastic-carbonate shelf, and also to increase the knowledge about the diagenetic process.

Considering the marlstones:limestones ratio, five composite third-order sequences were recognized, each one subdivided into a transgressive system track and a regressive system track. No relation was observed between sequence stratigraphy and clay mineralogy, except for the regressive system track of Quintuco Fm, that is characterized by an important increase in clay mineral content, specially illite/mica.

Marlstones represent the main lithology in the VacaMuerta Fm and XRD analysis revealed that clay mineralogy is dominated by illitic material, with subordinated rich Fe-chlorite. Illitic material is characterized by very little amount of expandable layers. Limestones also present Fe-rich chlorite and illitic material with a subtle increase in expandable layers. Tuffs may show either alteration to argillaceous minerals (80%) or replacement by carbonate material (20%) (calcite and dolomite), the clay fraction revealed an important amount of Fe-rich chlorite and also interstratified illite/smectite (I/S), and, when compared to marlstones, the I/S of the tuffs presents an increase in the amount of expandable layers. The high amount of Fe-rich chlorite on tuffs deposits is expected considering the high amount of Fe-rich minerals in tuffs sediments. On the other hand, Quintuco Formation shales are characterized by illite/mica, chlorite and small amounts of I/S. The great abundance of illite/mica evidences the progressive shallowing upward system, reflecting an important increase of detrital input.

Illitic material represents the main clay mineral in VacaMuerta Fm. This fact may support the idea proposed by Wilson *et al.* (2016) who mentioned that I/S (R3) may, under particular conditions, crystallize from pore waters. The high-ordered I/S is consistent with other indicators such as pyrolysis analysis, that revealed $T_{max} \sim 520^{\circ}C$, characterizing this system as an overmature formation in PuertaCuraco. The difference observed on expandable layers in tuffs (carbonated or argillaceous replaced) suggests different initial material for marlstones and for tuffs, conditioning the formation of different clay mineral associations during diagenesis.

Preliminary interpretations indicate that clay minerals in VacaMuerta Fm mainly respond to diagenesis processes, while Quintuco Fm clay mineralogy may be dominated by detrital input. Finally, the advanced stage of the illitization process observed in PuertaCuraco section, is compatible with other indicators like pyrolysis analysis, characterizing the system in this part of the basin as an overmature formation.

- [1] Kietzmann D., Ambrosio A., Suriano J., Alonso, M.S., González Tomassini F., Depine G., Repol D. (2016). The VacaMuerta-Quintuco System (Tithonian-Valanginian) in the Neuquén Basin, Argentina: A view from the outcrops in the ChosMalal fold and thrust belt. AAPG Bulletin, V.100, No. 5, p. 743-741.
- [2] Wilson, M.J., Shaldybin, M.V. and Wilson, L. (2016). Clay mineralogy and unconventional hydrocarbon shale reservoirs in the USA. I. Occurrence and interpretation of mixed-layer R3 ordered illite/smectite. Earth-Science Reviews 158, p. 31-50.