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Silurian succession from North Africa - Sedimentology and thermal history for a new era of hydrocarbon exploration

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The economic potential for unconventional shale oil and gas production in the Silurian of the Berkine – Ghadames and Illizi basins (BGI) was recently confirmed through exploration drilling in south-eastern Algeria. The conducted research focuses on the southern margin of the prolific BGI basins, i.e. the Tassili n'Ajjer plateau, and aims to understand and characterize in great detail the depositional environments and sequences of the entire Silurian deposits, as well as to reconstruct the diagenetic and thermal history of the region.

Over the Tassili n'Ajjer plateau, Silurian succession is composed of three Formations, namely from bottom to top: the *Oued Imihrou* Formation, overlained by the *Atafaïtafa* and the *Oued Tifernine* Fm. The 400 m-thick clastic strata of this succession, laterally traceable over kilometers, are showing progressively a general trend of thickening- and coarsening-upward (shallowing-upward) with exceptional variability of depositional environments, as evidenced by their numerous associated sedimentological and ichnological features. Indeed, the wealth of outcrop data within the Silurian succession enables us to distinguish thirteen facies (facies A-M), ranging from shallow-to marginal-marine facies. Furthermore, the sequential analysis of this succession was carried out following the identified characteristics of each facies and ichnofacies, as well as the integration of magnetic susceptibility, gamma-ray spectrometry, and geochemical results. Using this multidisciplinary approach, six 3rd-order sequences have been identified (in ascending order, Si-1 to Si-6). Most, if not all, of the levels with abnormally high values of magnetic susceptibility and gamma-ray, correspond to key surfaces of the aforementioned depositional sequences, i.e. the maximum flooding surfaces, therefore, highlighting the global sea-level rises within the Silurian Period.

Investigation of the diagenesis- and thermal maturity-evolution of the Silurian succession during the present study led to significant conclusions. Our results and interpretations, both on graptolite-derived organic matter maturity and evolution of clay minerals, reveal an important relationship between kerogen maturation with episodic illite crystallization and the structural evolution in SE Algeria. Indeed, the repeatedly reactivated N-S lineaments and mega-shear zones, during the Phanerozoic orogeneses and rifting phases, constituted migration pathways for hot potassium-rich fluids. These migration pathways, notably at the westernmost part of the Tassili n'Ajjer plateau, induced thermal anomaly or brief 'heat spike' as revealed by higher organic maturation level and subsequent precipitation of authigenic clay minerals.

Lastly, from the standpoint of Silurian oil and shale gas future exploration in the eastern Sahara, it is important to highlight that the areas of interest 'Plays' could be most likely those bordering major Precambrian lineaments, i.e. Amguid-El Biod-Messaoud axis, where thermal maturation and unrestricted hydrothermal fluids are high and frequently reported. In other words, these promising areas are undoubtedly offering the highest potential with more discoveries of natural resources in Algeria.

Keywords: Tassili n'Ajjer plateau, Silurian, black shales, sedimentary structures, graptolite, diagenesis, illite, thermal history.