Comparative Analysis of CO_2 Sequestration Potential in Shale Reservoirs: Insights from the Longmaxi and Niutitang Formations

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1. Introduction

Shale reservoirs, characterized by their extensive nanopore networks and heterogeneous pore structures, hold significant promise for CO_2 sequestration. This study investigates the storage and sequestration potential of shales from two formations: the Lower Silurian Longmaxi Formation (TY1) and the Lower Cambrian Niutitang Formation (N206). A comprehensive suite of methods, including XRD analysis, mercury intrusion porosimetry (MIP), low-pressure gas adsorption (N_2 and CO_2), field-emission scanning electron microscopy (FE-SEM), fractal and multifractal analysis was employed to characterize pore structure, adsorption behavior, and mineralogical controls on CO_2 storage.

2. Mineralogy and SEM Morphology

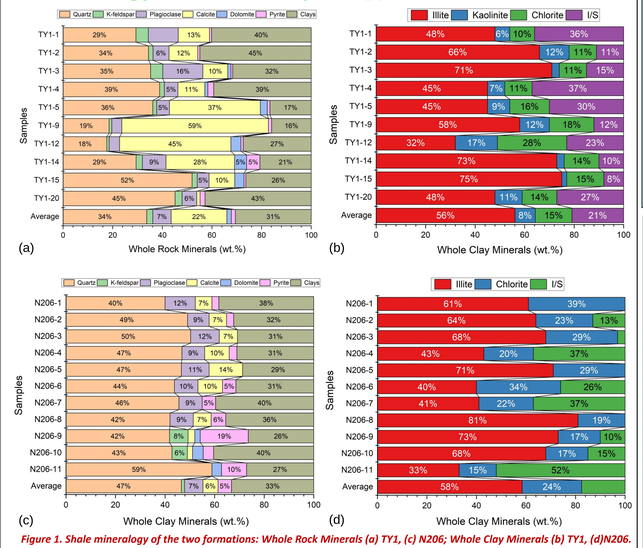

Figure 1. Shale mineralogy of the two formations: Whole Rock Minerals (a) TY1, (c) N206; Whole Clay Minerals (b) TY1, (d)N206.

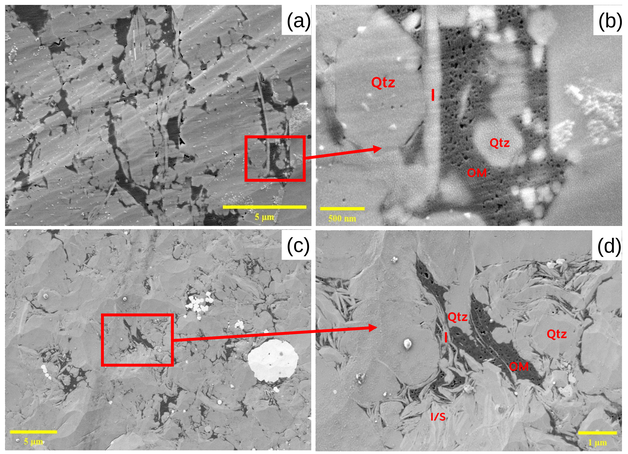

Figure 2. Authigenic quartz and clays supporting OM-hosted pores: TY1, (a) and (b); N206, (c) and (d).

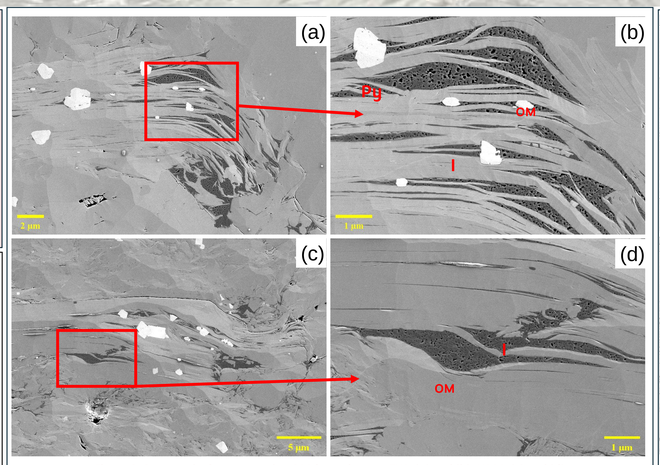

Figure 3. Syngenetic clays preserving OM-hosted pores: TY1, (a) and (b); N206, (c) and (d).

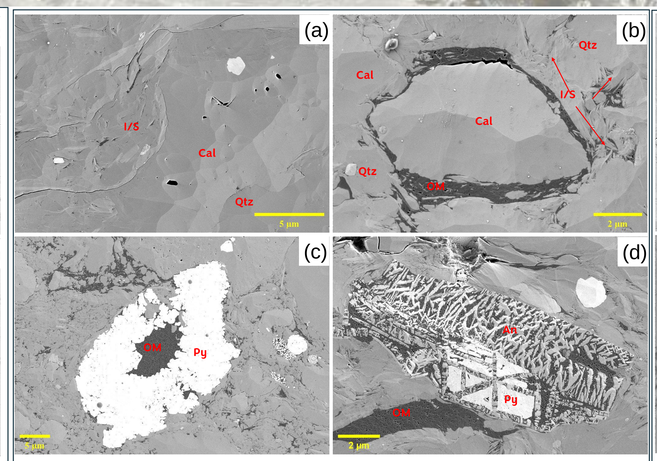

Figure 4. Carbonates, pyrite and authigenic anatase with OM: TY1, (a) and (c); N206, (b) and (d).

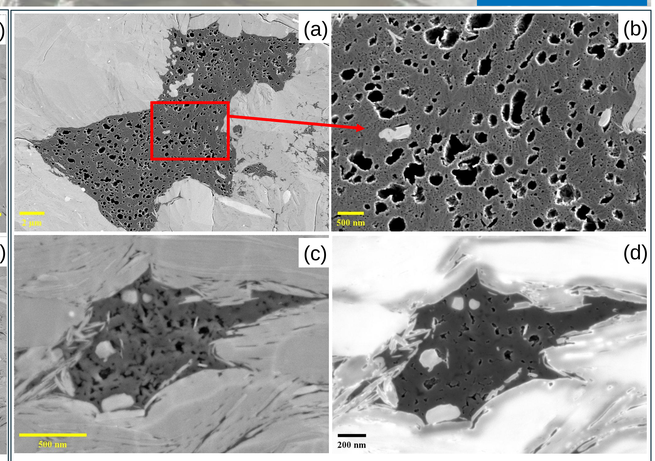

Figure 5. OM-hosted pores comparison: TY1, (a) and (b); N206, (c) and (d).

3. N_2 Adsorption/Desorption and CO_2 Adsorption Experiments

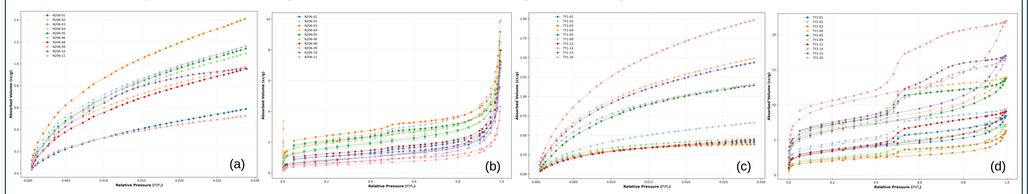

Figure 6. Low pressure CO2 isotherms obtained from (a) N206 and (c) TY1; Low pressure N2 sorption isotherms from (b) N206 and (c) TY1.

4. Multifractal Analysis

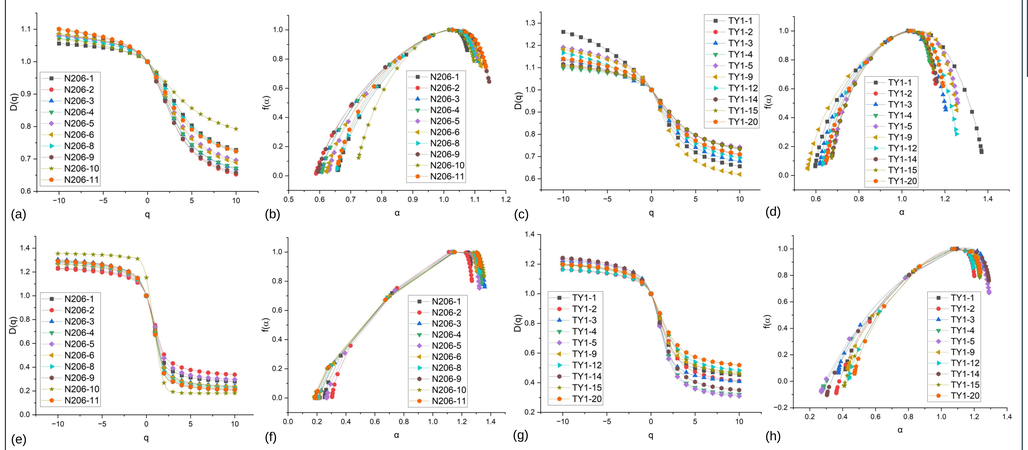

Figure 7. Relationship between Dq and q from low pressure CO2 adsorption isotherms for (a) N206 and (c) TY1; Multifractal singularity from low pressure CO2 adsorption isotherms for (b) N206 and (d) TY1; Relationship between Dq and q from low pressure N2 adsorption isotherms for (e) N206 and (g) TY1; Multifractal singularity from low pressure N2 adsorption isotherms for (f) N206 and (h) TY1.

5. Shale Pore Structures

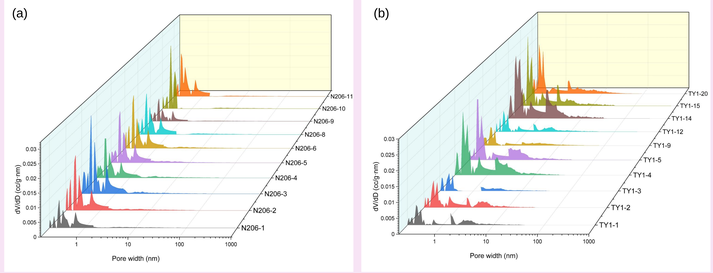

Figure 8. Pore size distributions obtained from MIP and low-pressure gas (CO2 and N2) sorption analysis: (a) N206; (b) TY1

6. Summary

- TY1 samples exhibit higher total organic carbon (TOC; up to 7.58%), greater micro- and meso-porosity, and stronger CO_2 adsorption energies (up to 34 kJ/mol) compared to the N206 samples, which display a more micropore-dominated system and lower adsorption energies (28–30 kJ/mol).
- Quartz, clay, and OM controls on pore heterogeneity and connectivity are both observed in the two formation. Meanwhile, the FE-SEM observations revealed that many authigenic minerals such as quartz, pyrite and rutile occupies the pore space in organic matters. It is much more prevalent in the N206 samples, which may responsible for its lower meso-prosity.
- The Longmaxi Formation demonstrates superior pore connectivity and pore size distribution (PSD) homogeneity, enhancing both CO_2 retention and transport. The TY1 group's balanced micropore and mesopore contributions make it ideal for long-term CO_2 sequestration over N206 group.

Main References

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