Upper Ordovician-Lower Silurian Gas Reservoirs in southern Sichuan Basin, China*

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Abstract

Extensive later Ordovician and initial early Silurian black marine shales are important Paleozoic source rocks deposited in a partly restricted environment related to a worldwide transgression in Southern Sichuan Basin, Upper Yangzi platform, China. Lowermost Longmaxi Formation is organic-rich black graptolitic shale with subordinate limestone and siltstones overlain by grey greenish shale and siltstone. Hirnantian Stage Kuanyinqiao Member between Longmaxi and Wufeng Formation preserves Hirnantia-Dalmanitina fauna in the marlstone and calcareous mudstone. Lower Silurian in Southwestern and Middle-Lower Silurian in Southeastern Sichuan Basin only remain for the erosion due to Caledonian movement.

The average total organic content of the target interval for shale gas is about 3 wt. % that is the consequence of hydrocarbon generation and expulsion during higher maturation (Ro 2.3-3.4%). Fieldworks in the Southern Sichuan provided some preliminary insight into the good potential for shale gas of lowermost Silurian ‘hot’ graptolitic shale. Widespread gas shows presented in Silurian Formation in drilled wells. In some cases, the elevated gamma-ray and resistivity values suggest the presence of the “hot” shale. The first shale gas exploration well further proves good gas content in the cored interval with a typical response on wireline logs. In addition, one of significant characteristics of Longmaxi target interval is that a great deal of micropores and nanopores are well developed in organic matter at higher maturity that the remaining hydrocarbon potential is almost zero, though its petrology, bioclasts layers, primary pore spaces, and types are unique compared with those of Barnett Shale in core area, Eagle Ford Shale in outcrop and etc.. Moreover, Silurian “hot” shale and later Ordovician Wufeng Formation are enveloped by lower tight Baota Limestone, primary frac barriers. The grey greenish organically lean shale may be a weak upper barrier.

Upper Ordovician-Lower Silurian shale analysis of logs, Pyrolysis, thin-sections, CL, QEMSCAN, XRD, and XFD indicate that the vertical lithological variations and fabric anisotropy are notable, not only the clay (mainly illite), carbonate, quartz, and pyrite content, but the primary origin and geological evolution. Integrated data sets can be used to characterize several lithofaces units rather than a whole homogeneous unit as the porosity, permeability, and geomechanical properties of “hot” shales can be related to the lithologies. We conclude that there is a strong potential of shale gas in southern Sichuan Basin, despite it poses different challenges for the development of higher and over maturity black shale.

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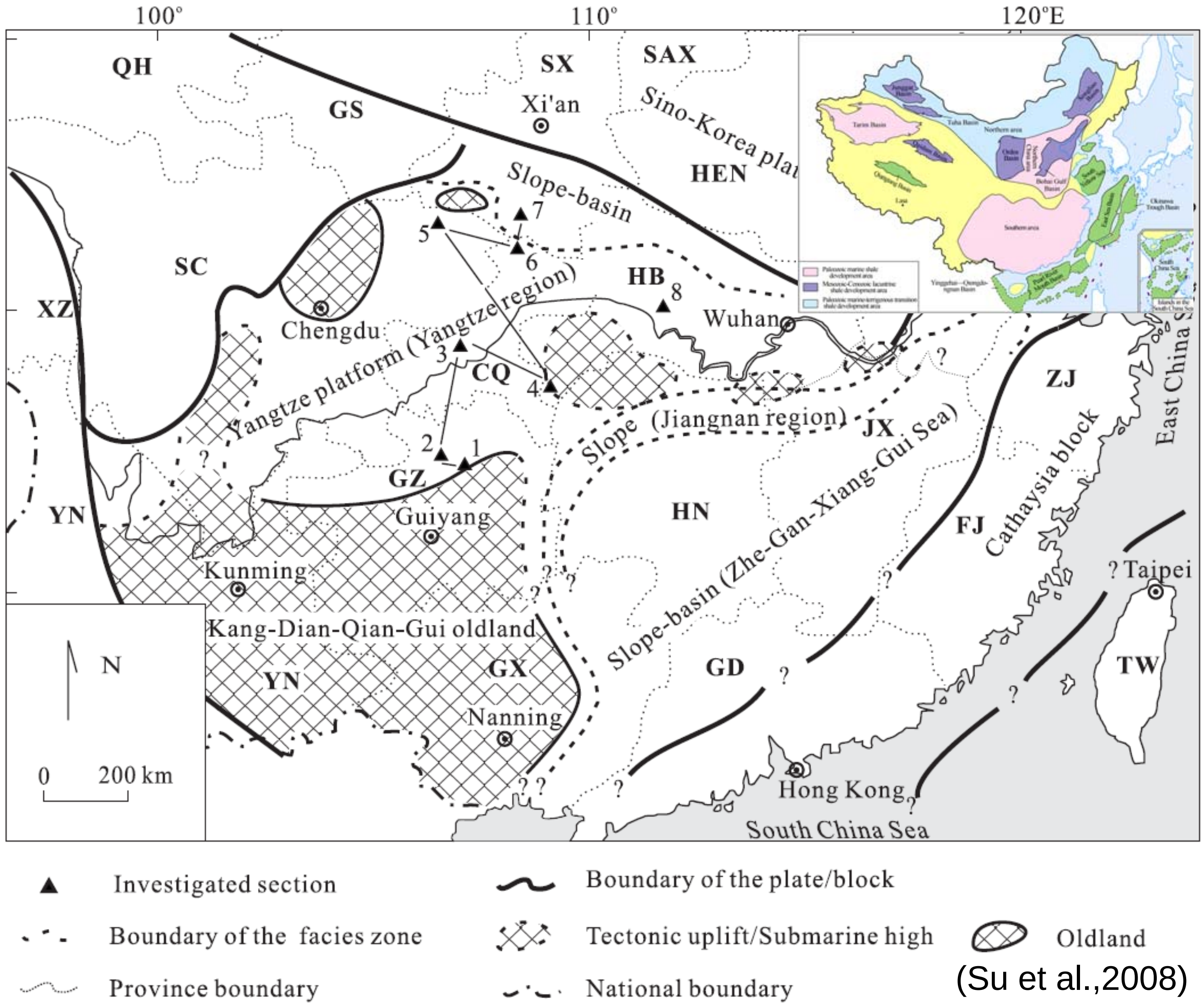
Outline

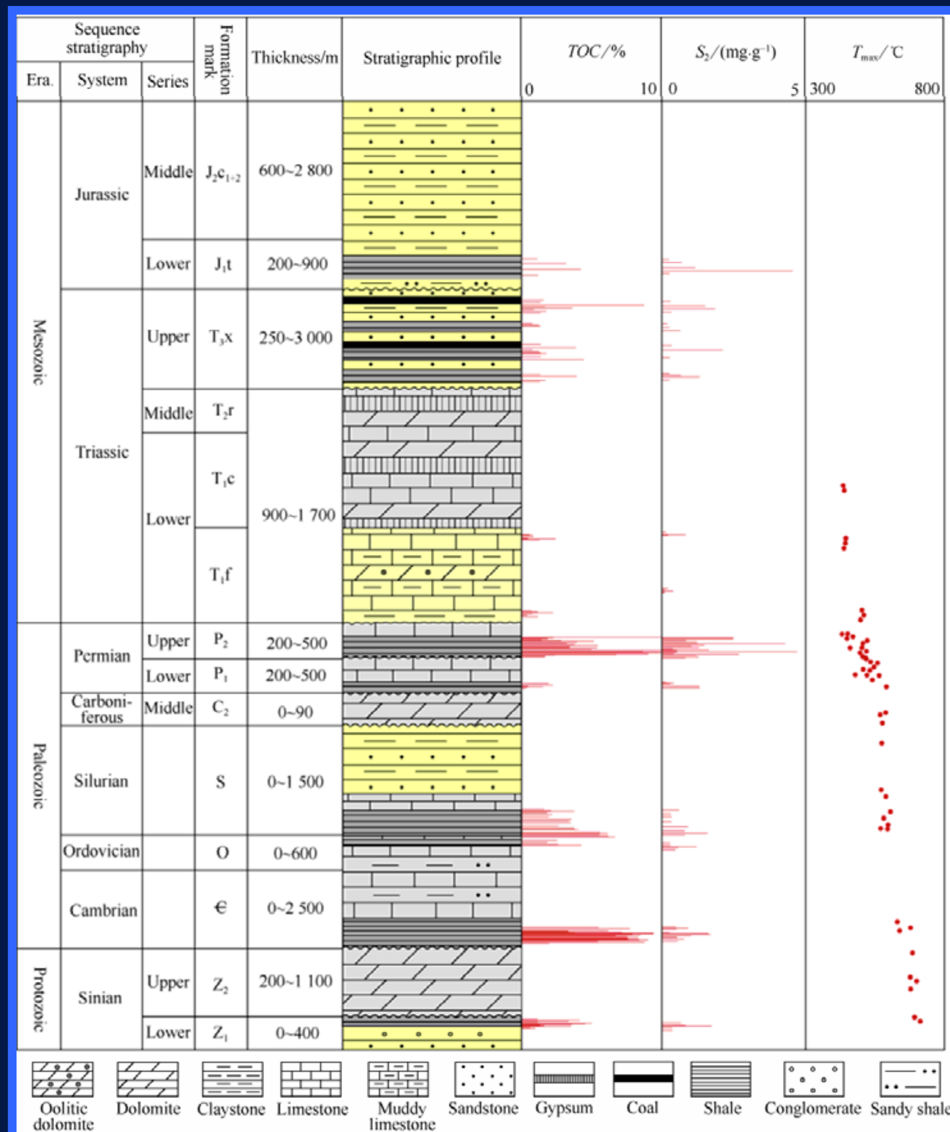
- Geologic overview
- Minerals and lithology
- Pores spaces and types
- Summary and discussion

Late Ordovician Tectonic Units and Sedimentary Facies in Southern China



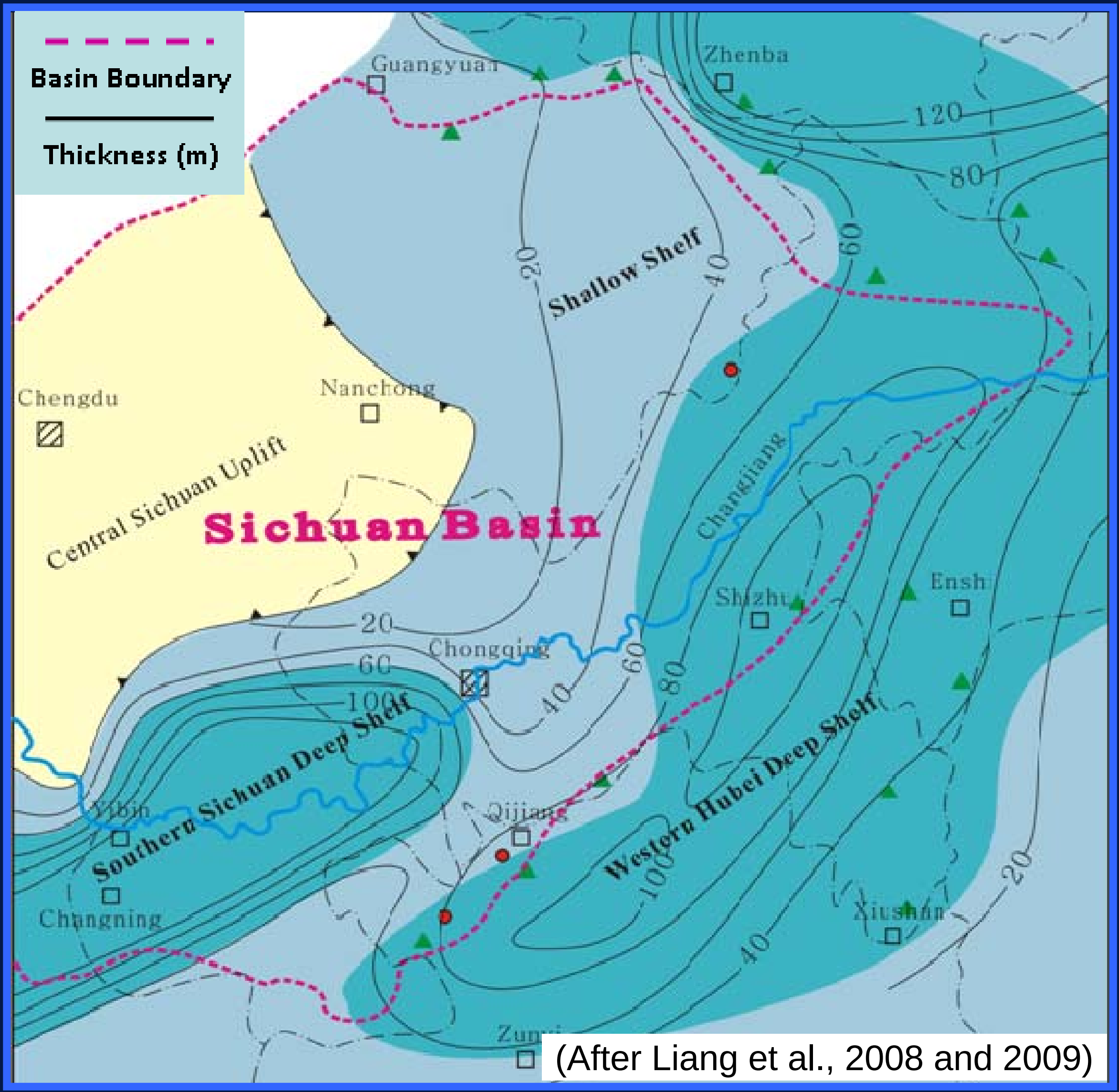
(Su et al.,2008)

Stratigraphy and Paleozoic "Hot Shales" of Sichuan Basin



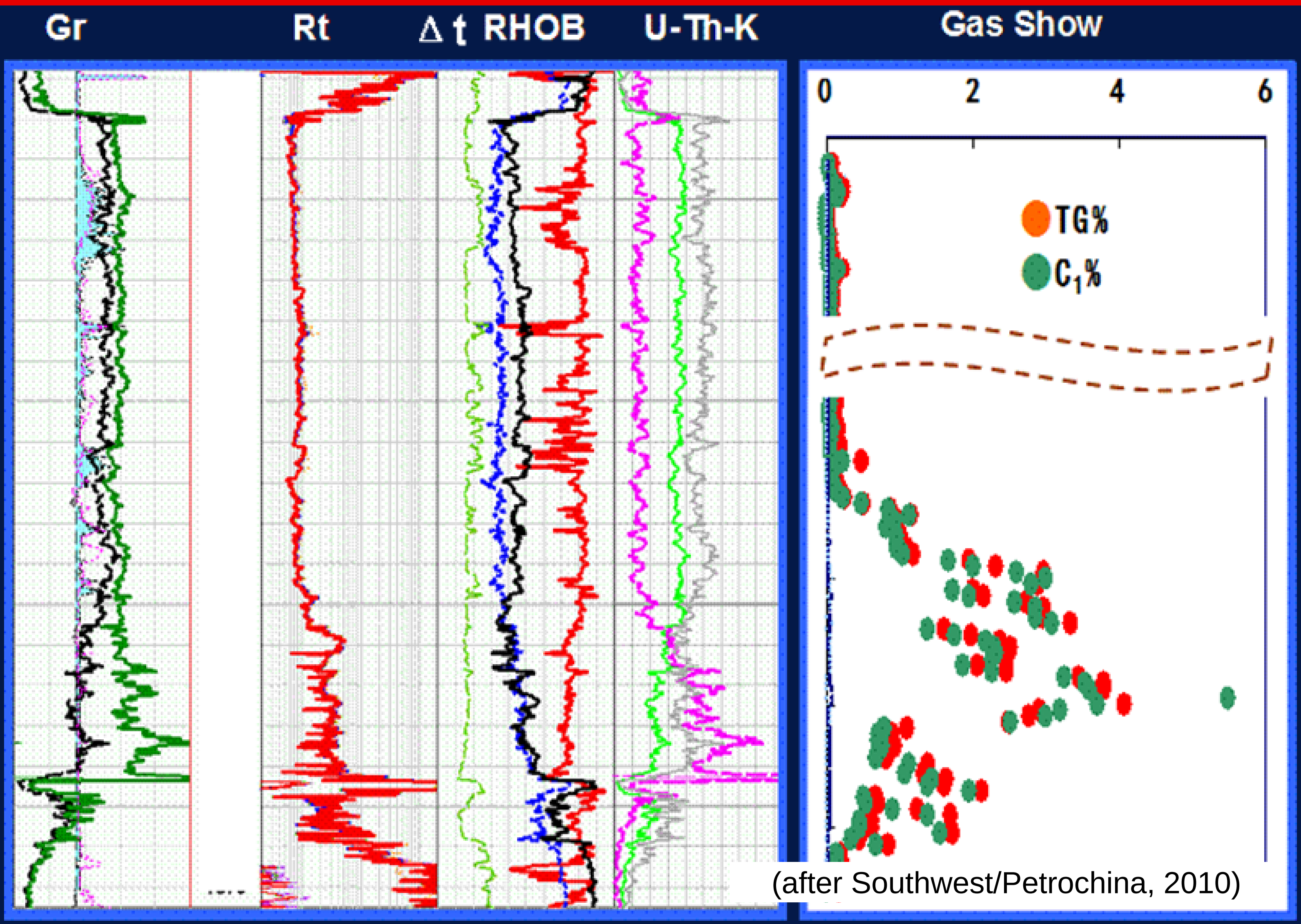
(Zou et al., 2010)

Isopach Map of Upper Ordovician-Lower Silurian Source Rocks



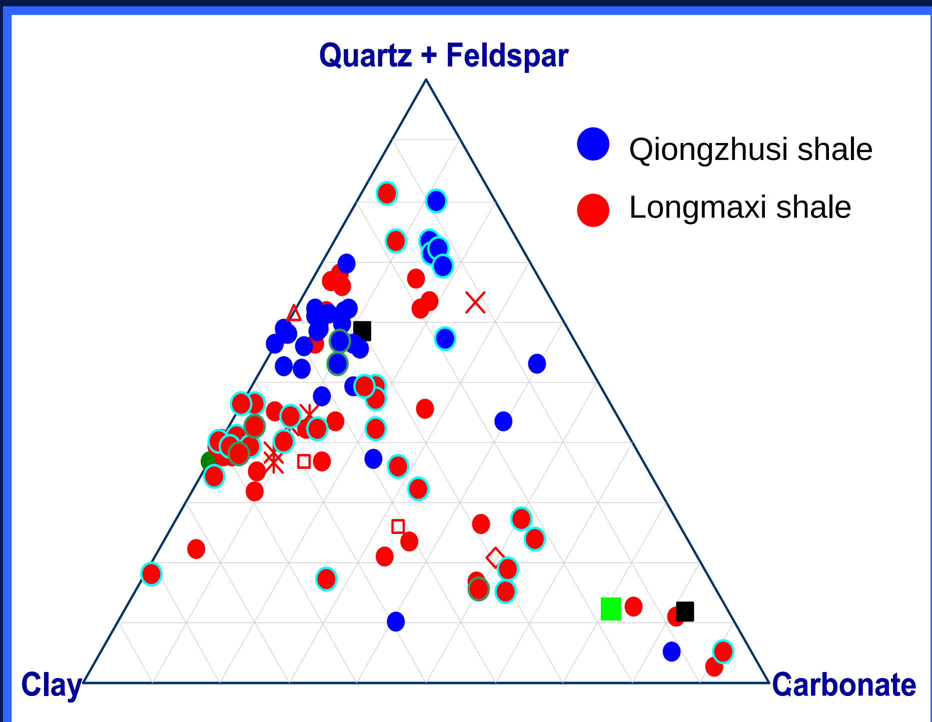
(After Liang et al., 2008 and 2009)

Target Prospect for Longmaxi Shale (S_1l)

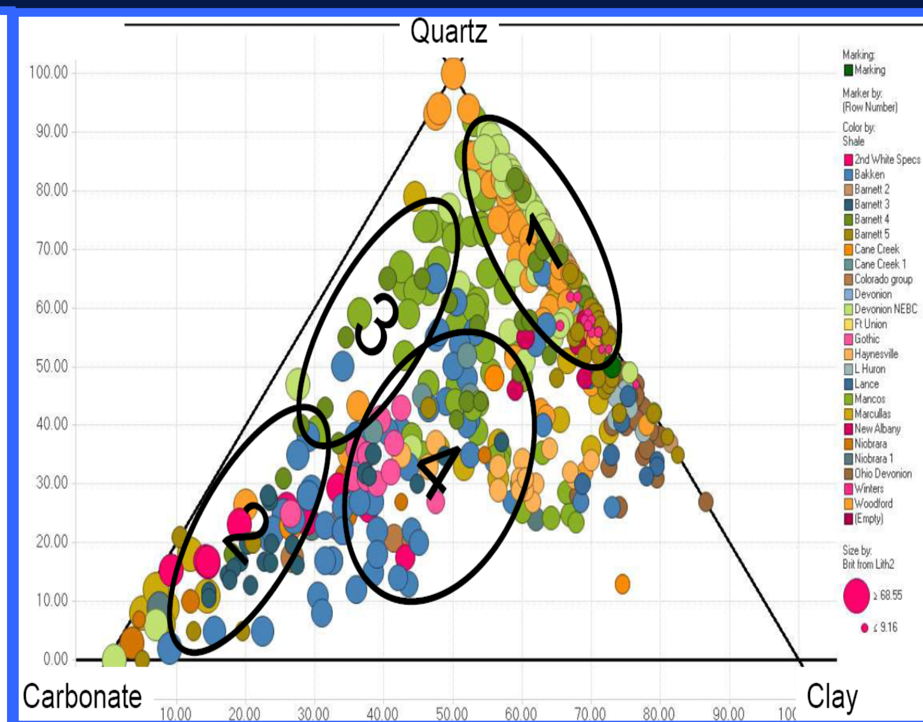


(after Southwest/Petrochina, 2010)

Mineral Composition and Heterogeneity



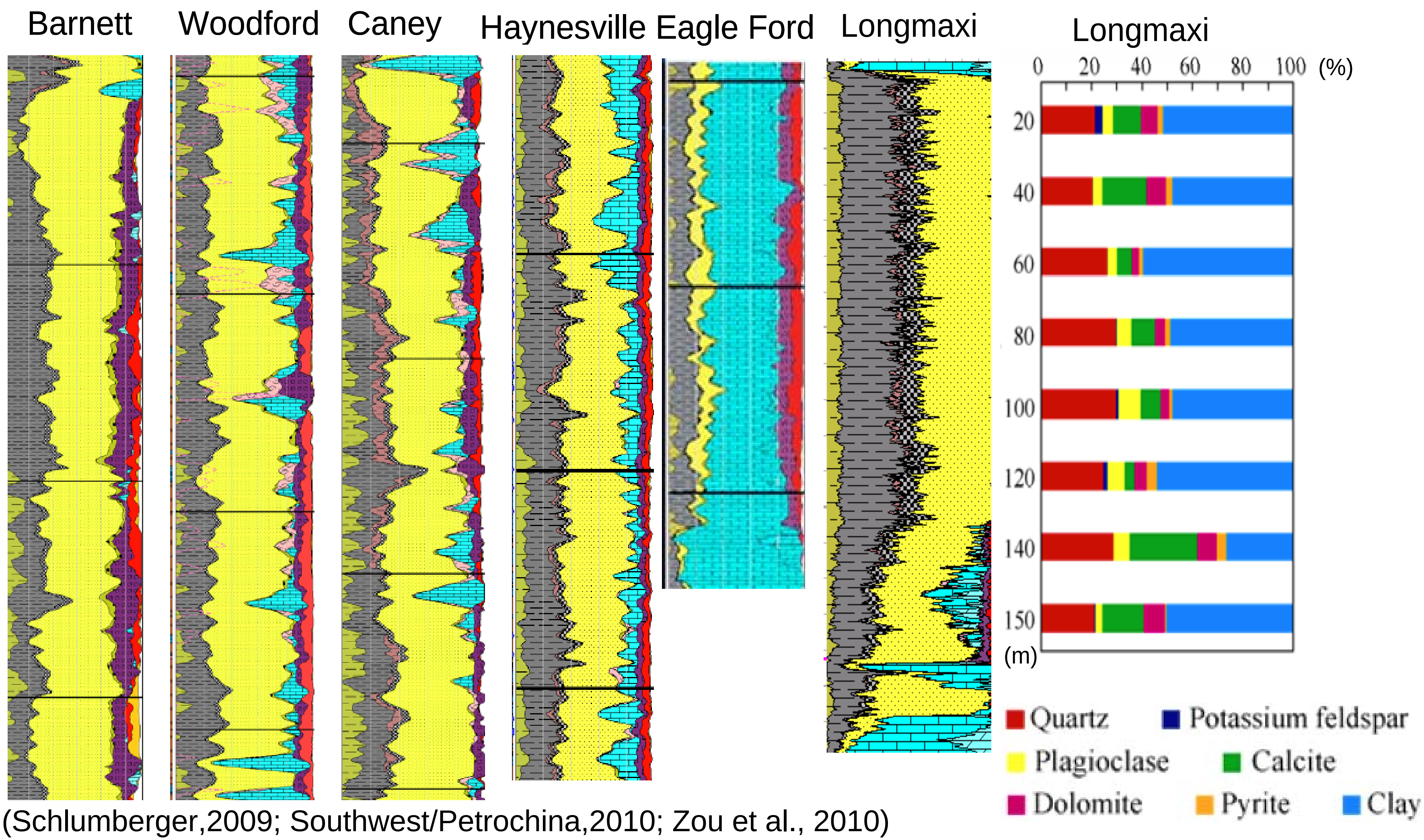
(Li, 2010)



(Halliburton, 2007)

Triangular diagram of mineral composition

Mineral Composition for Different Shales



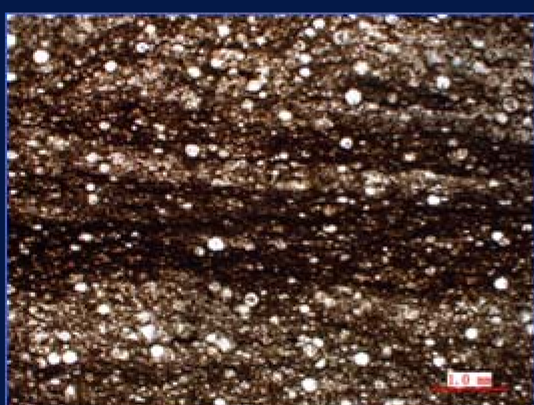
(Schlumberger,2009; Southwest/Petrochina,2010; Zou et al., 2010)

Hot Shales with Rich Bioclasts Layers

Barnett :TOC=2.05%
Quartz=51%±;Clay=37%±
Carbonate=12%±

Barnett: TOC=1.33%
Quartz=25.7%;Clay=24.7%
Carbonate=40%

Eagle Ford: TOC=5.25%
Quartz=17.3%;Clay=13.3%
Carbonate=64.9%



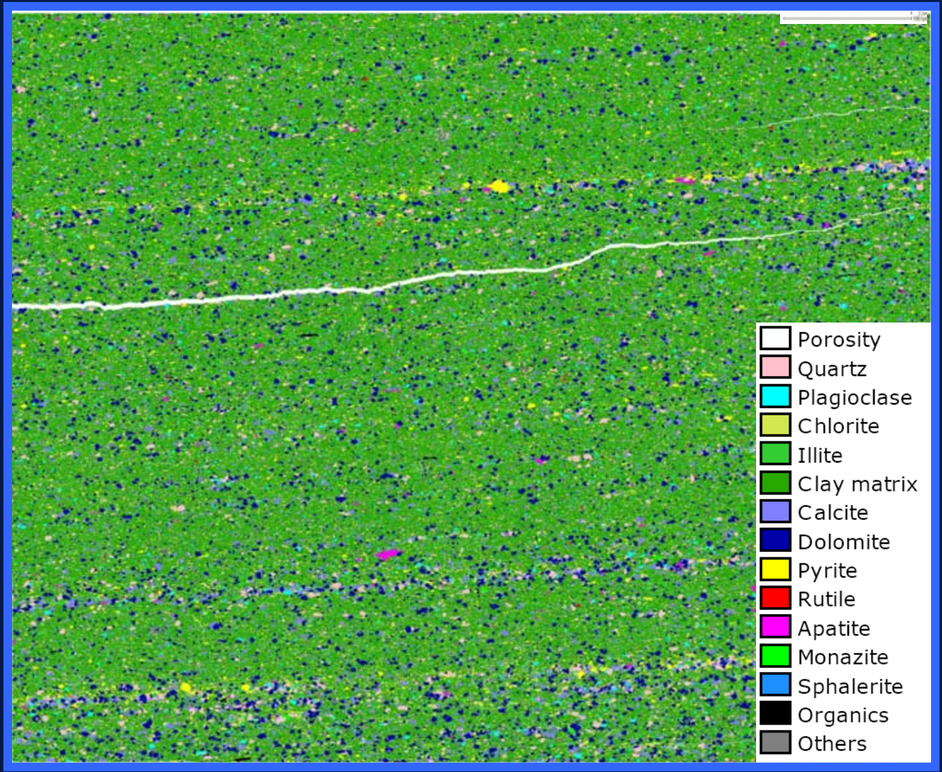
Weiyuan county -O_3w

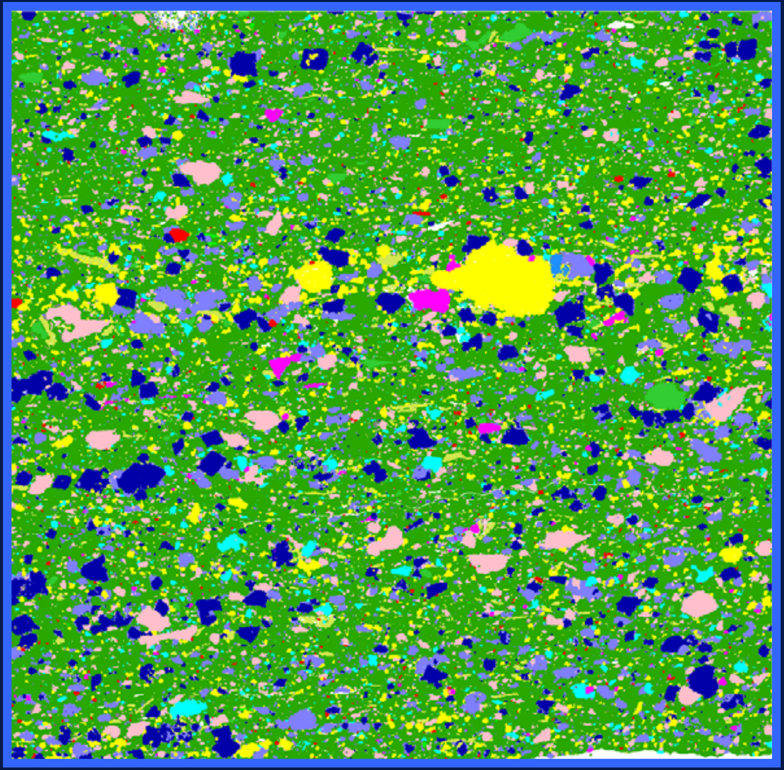
Changning county -O_3g

Qilin county – S_1l

Bioclast layers alternating with clay- and organic matter rich layers

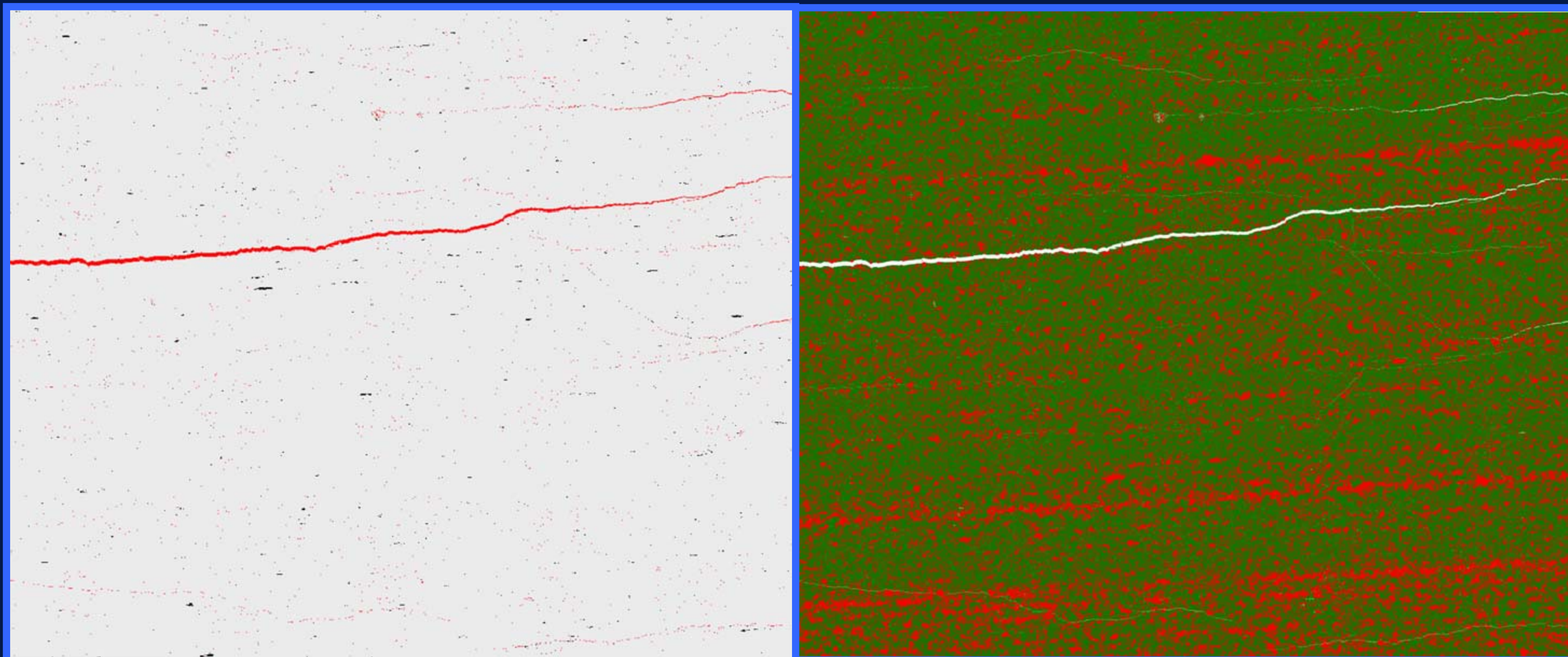
QEMSCAN Longmaxi Shale Petrology





QEMSCAN false colour image showing the lamination of very fine carbonate and quartz grains

QEMSCAN Longmaxi Shale Pores and Textural Occurrence

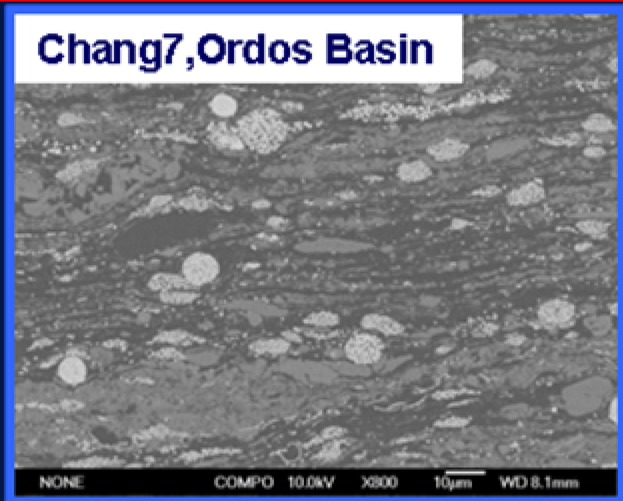


Left: Organics (black) and Pores (red)

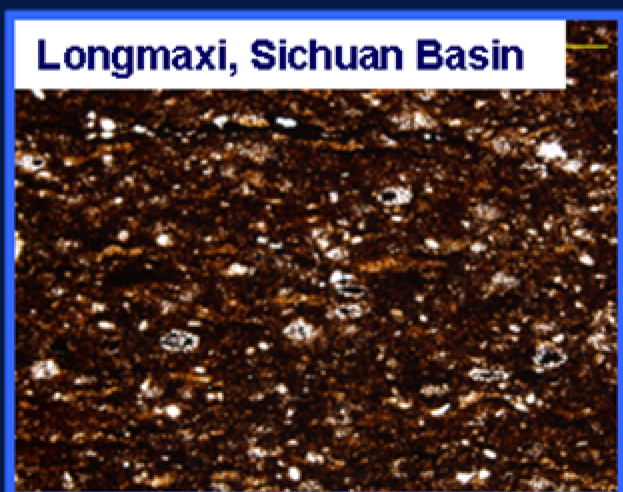
Right: Ductile minerals (green) including clays, micas and organics

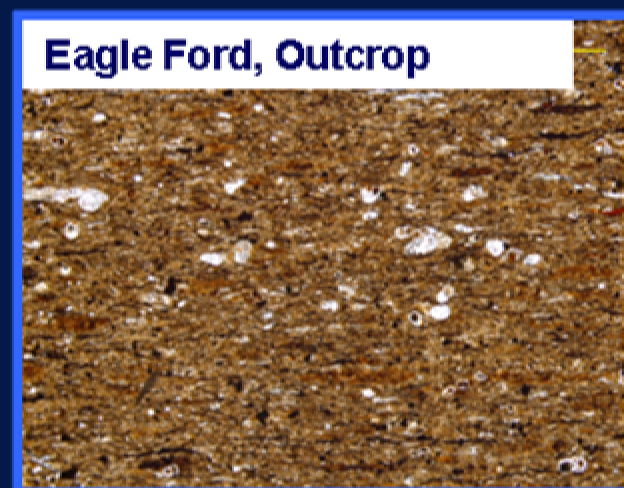
Brittle minerals (red) including all other inorganic minerals

Two Patterns of Organic Matter Disposition



Two Basic Patterns

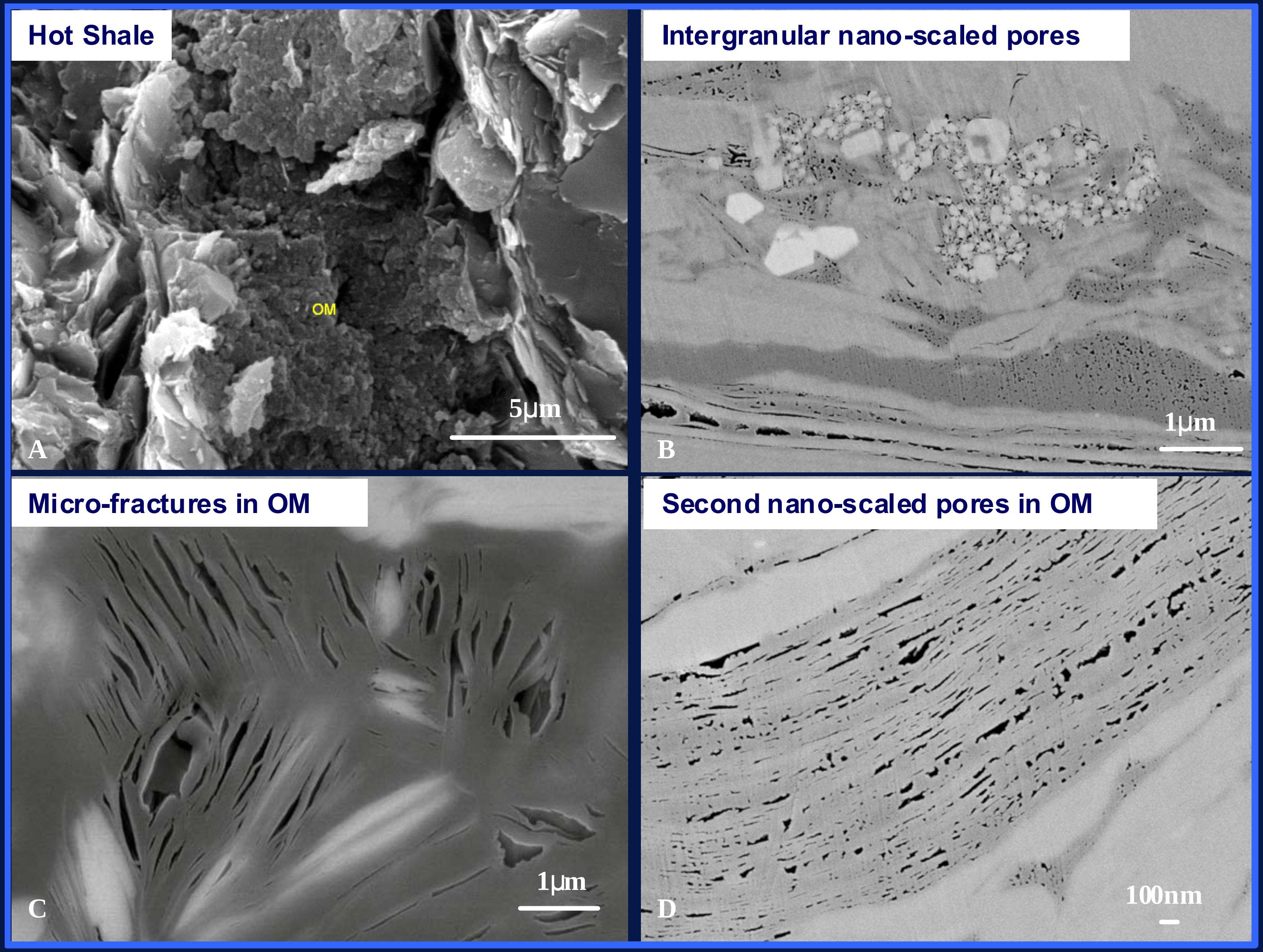




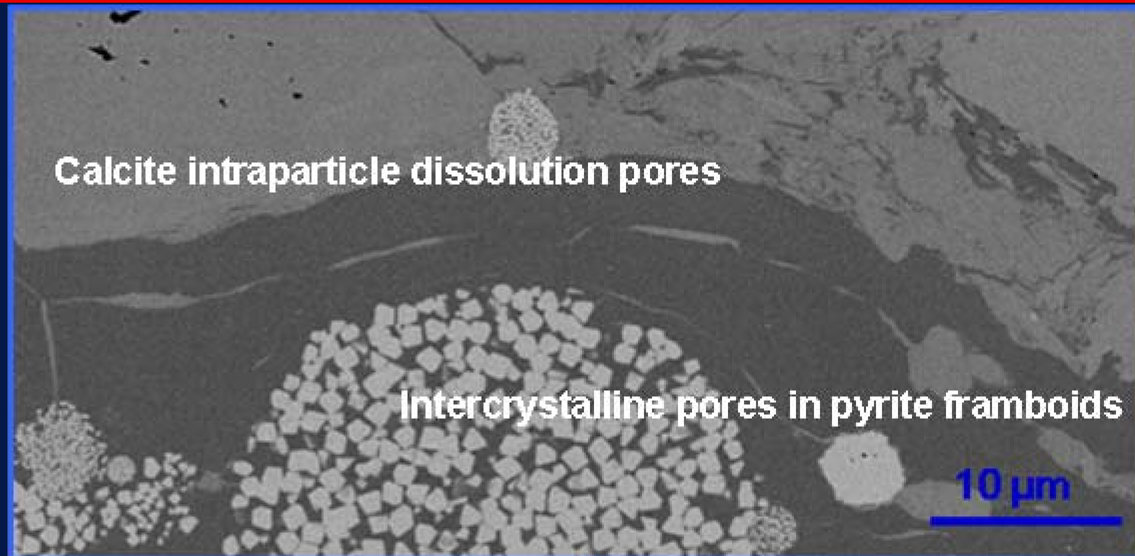
Middle Pattern

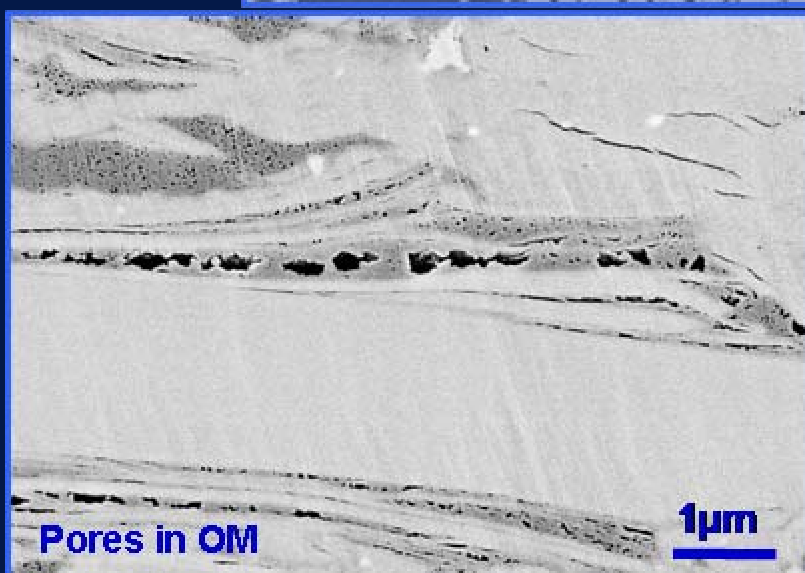
Laminated and minute horizontal bands indicating the carbon-rich kerogen layers

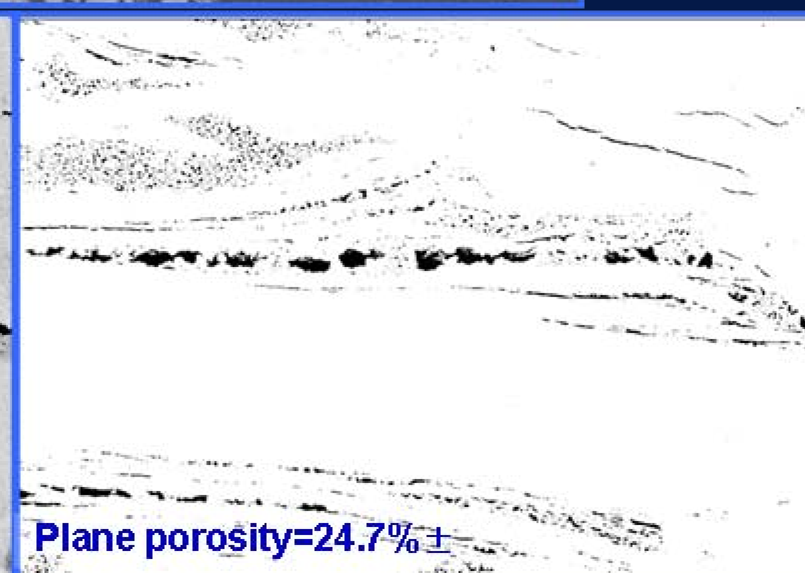
Pore Spaces and Types of Longmaxi Hot Shales



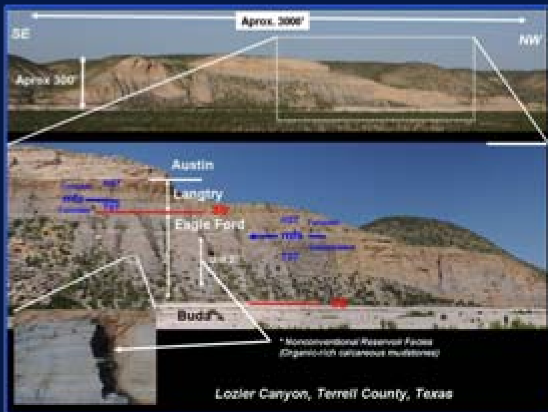
Pore Spaces and Types of Longmaxi Hot Shales



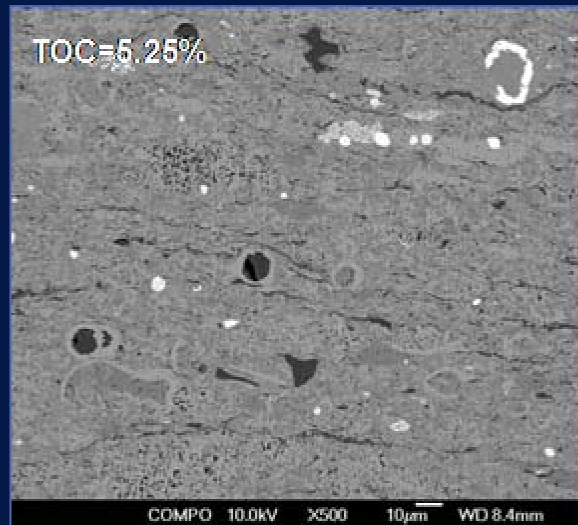


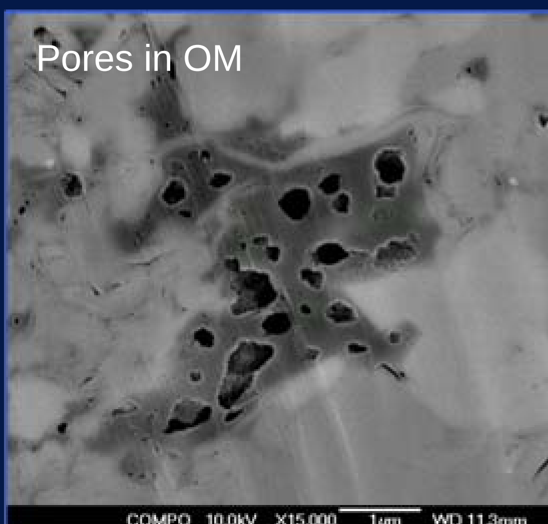


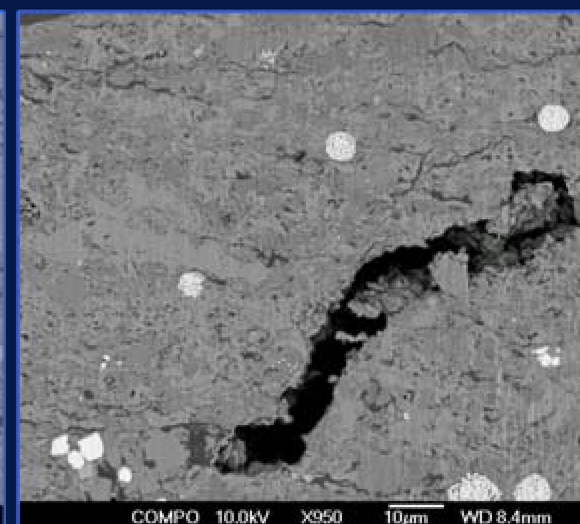
SEM image of Secondary Dissolution Pores for Eagle Ford Shale



Outcrop in south Texas
(AAPG Hedberg conference, 2010)

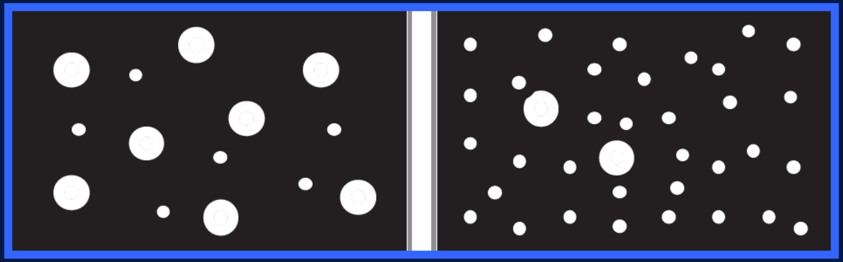






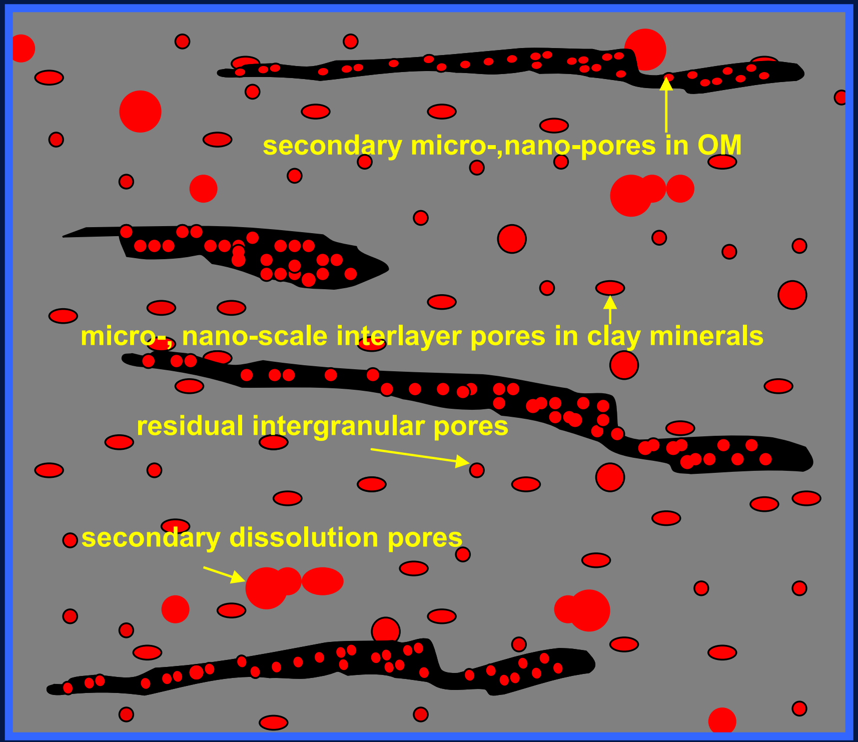
Conceptual Model for the Origin of Shale Pores

Sandstone

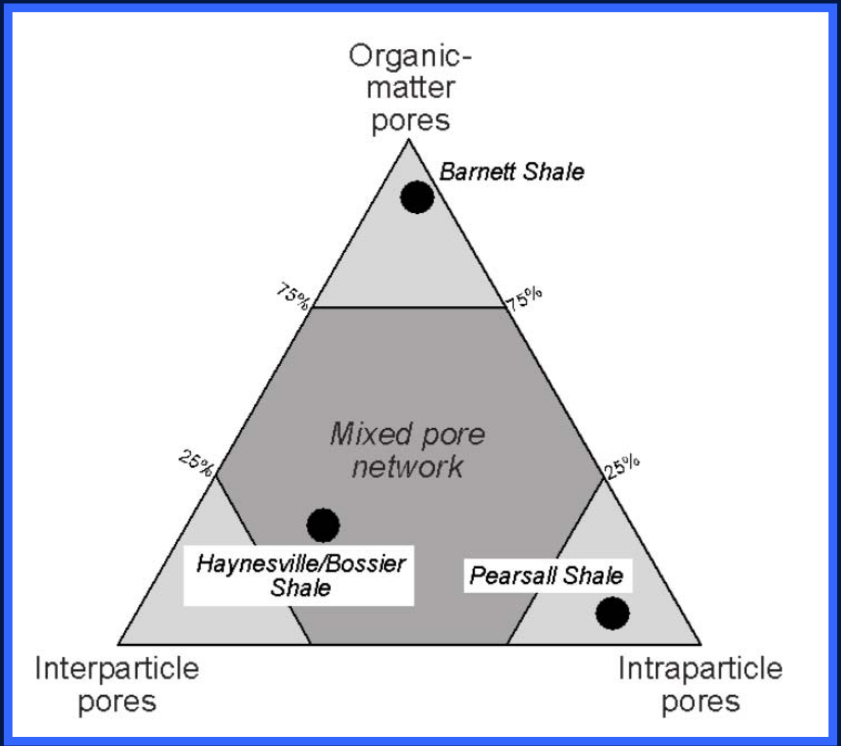


Shale

(Javadpour et al., 2007)

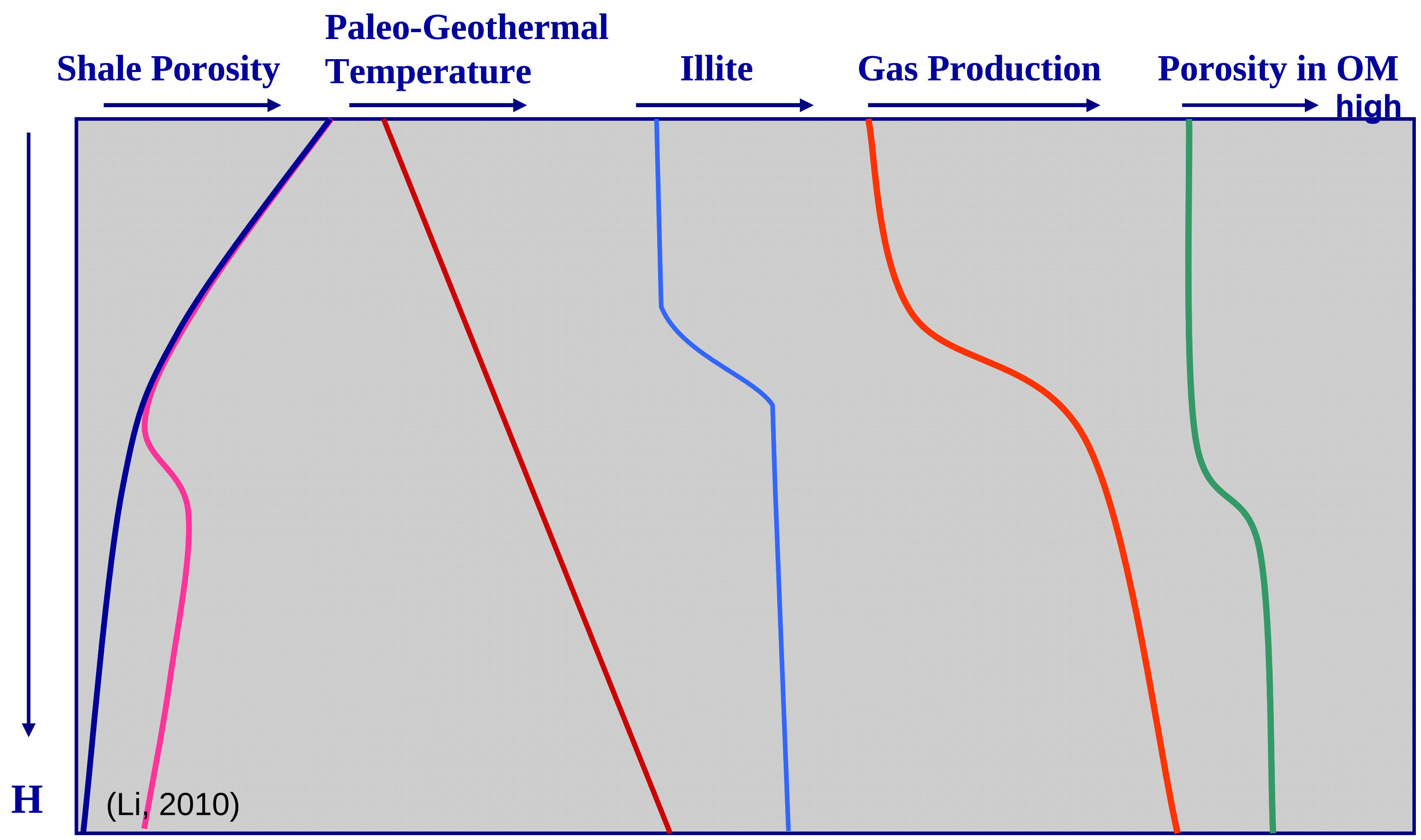


(Li, 2010)



(Loucks et al., 2010)

Geological Evolution of Porosity



Summary and Discussion

1. Unconventional gas resources is not an issue for over-thermal maturity marine shales in Southern Sichuan Basin.

2. Shale reservoirs are heterogeneity and the laminations are of quite different textural features between detrital silt and matrix silica, calcareous fossil debris and authigenic calcite and dolomite, organic matter and inorganic minerals, ductility and brittleness.

3. Potential productive gas shale systems are mainly composed of different types of porous media.

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Thanks for Your Attention!

QUESTIONS?