Variations of gas reservoir properties, many of which reflect the physical and chemical nature of the depositional environments of the reservoir rocks, can be linked to base level fluctuations. The resulting sequence stratigraphic framework, then, can be extrapolated into regions of minimal data control. Our sequence stratigraphic paradigm is based on the transgressive-regressive (T-R) sequence concept. A single T-R sequence comprises transgressive systems tract (TST) deposits overlain by a regressive systems tract (RST) succession, the contact being a maximum flooding surface (MFS), and is bounded on top and bottom by maximum regressive surfaces. Ongoing studies of the Devonian shale succession of the Appalachian Basin reveal that such parameters as mineralogy and microfabric vary predictably within the T-R sequence stratigraphic framework. A general increase in silica, much of which is diagenetic, and reduction of clay upward through the TST reflects the rapid landward migration of the shoreline. Early precipitation of silica cement preserves porosity and inhibits the development of a planar clay grain microfabric. TST deposits are commonly pyritiferous and organic-rich; indeed, TOC and pyrite content are maximum close to the MFS. Increasing thermal maturity of these deposits is accompanied by increasing porosity (principally nanoporosity) as a consequence of the transformation of kerogen. Under some conditions, bacterial reworking of organic-rich sediment deposited during transgression, especially proximal to the base level maximum, results in suppression of vitrinite reflectance. Accumulation of RST deposits is marked by increasing terrigenous sediment flux (clay and detrital quartz) and concomitant dilution of the organic contribution. This favors the more widespread development of a strongly planar clay-grain microfabric disrupted only by discrete laminae of detrital quartz or isolated grains. The base level minimum is defined by minimal TOC and local carbonate horizons. The predictive capabilities inherent to sequence stratigraphy make it especially applicable to exploration programs of seemingly homogenous shale successions.
References


Sequence stratigraphy and its bearing on reservoir characteristics of shale successions - examples from the Appalachian Basin

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sequence stratigraphy and reservoir properties...

...stresses processes, correlation and prediction...

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*Sedimentology* - processes of sedimentary rock formation

(Within the confines of individual depositional systems)

- **Sequence Stratigraphy:**
  - processes
  - correlation
  - prediction

- **Stratigraphy:** correlation and attributes of rock strata

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*Sedimentology:* the scientific study of sedimentary rocks and of the processes by which they form.

*Stratigraphy:* the science of rock strata - all characters and attributes of rocks as strata, and their interpretation in terms of mode of origin and geologic history.

*from Catuneau, 2006*
...reservoir architecture and characteristics are driven largely by relative rates of sedimentation and subsidence and consequent base-level fluctuation...

...unique sedimentologic/stratigraphic attributes related to base level fluctuations that reflect their respective depositional histories, include a variety of parameters critical to reservoir properties that would be important to exploration and production strategies...
... transgressive-regressive sequence ...
T-R sequence ... outcrop example

- CSHAQUA SHALE
- MIDDLESEX SHALE
- WEST RIVER SHALE
- GENUNDEWA LIMESTONE
- MOSCOW SHALE
Genundewa Limestone

Moscow Member

wave-worked arenaceous limestone unconformably overlying marine mudstone (Moscow Member) ...
Genundewa Limestone

Moscow Member
Genundewa Limestone

Moscow Member

West River Member

increasing TOC; diminished wave activity

depthening up trend
Middlesex Shale
Moscow Shale
West River Shale
Genundewa Limestone
Moscow Shale

Cashaqua Shale

MFS
TST
depening up trend
RST

sequence boundary... unconformable shoreline ravinement
Middlesex Shale
Moscow Shale
West River Shale
Genundewa Limestone
Moscow Shale

Cashaqua Shale

RST
shallowing up trend

MFS
depening up trend

TST
sequence boundary... unconformable shoreline ravinement

RST
...recrystallized silica...dissolution of abundant biogenic grains...
greater abundance of clay in RST deposits fosters development of an anisotropic microfabric...
mudstone heterogeneity revealed by electrofacies analysis...

Macquaker and Jones, 2002
...detrital quartz...
Marcellus Shale

Union Springs Shale

Onondaga Limestone

Oatka Creek Shale

Purcell Limestone

Stafford Limestone

11% pyrite

CaCO₃

clay

qtz

weight %
...TST... increasing base level and related landward shift of depositional environments leads to 1) reduced clastic flux (clay and detrital quartz) and 2) increased abundance of bioclastic particles...

...elevated (diagenetic) quartz and reduced clay >>>> enhanced brittleness...
TOC vs. quartz

TOC (wt%) vs. QUARTZ

R = 0.66
role of ductile organic particles...
%Ro = 0.6-0.74%

$r^2 = 0.35$

gray shale (organic-lean)
Hanover Shale, Cashaqua Shale

black shale
Dunkirk Shale, Rhinestreet Shale
$r^2 = 0.77$

%Ro = 2.3%

development of generation induced nanoporosity...
$\%R_0 > 1.4$
%R₀ > 1.4
\( \% R_0 > 1.4 \)
...TST... depending on thermal stress (%Ro), porosity and permeability may increase from the base to top of the TST in response to increasing TOC...
strong correlation of pyrite and TOC...MFS/condensed interval
pyrite lag - basal black shale
incompressible pyrite framboiid
polyframboids...
TST and condensed section deposits...

abundant quartz, pyrite, and calcite - increased brittleness

abundant TOC - diminished brittleness
...base level fluctuations are accompanied by changes in sedimentary regime, sedimentation rate, clastic versus biogenic flux rates, environmental energy, and geochemical characteristics...

...such a dynamic interaction among such factors influences a multitude of reservoir properties important to exploration and production strategies...
...mineralogy (porosity, permeability, brittleness) ...

...microfabric (porosity, permeability) ...

...organic carbon content (reservoir quality, permeability, porosity) ...

...diagenetic components (microfabric, porosity, permeability)...

...fracture density (natural hydraulic fractures as well as fractures formed under absolute tension)...

...log response...

...maturity parameters – vitrinite reflectance...