PS Geologic Variability within the Marcellus Shale and its Relationship with Natural Fractures*

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Abstract

Within the Appalachian Basin, the Marcellus Shale is being exploited as a natural gas resource. Primary sedimentary characteristics of the rock, inclusive of mineralogy, organic matter abundance, and fabric play key roles in determining the manner in which fractures propagate through the rock, whereas trace element content may affect produced water chemistry. Uncertainty exists regarding the degree of spatial variability of these primary features at both local and regional scales. Using outcrop and laboratory analysis, this study attempts to spatially characterize heterogeneity within the Union Springs Formation. Expanding upon the framework provided by Karaca (2012)* for the fine-scale characterization of the Union Springs, this study provides detailed descriptions of three full Union Springs columns exposed in quarries and 105 associated samples. The data capture rock properties and document their variability at distances ranging between 160 m and 39,000 m distance from the reference column. Packages of rock possessing properties suggestive of specific depositional environments are organized into microfacies, based upon characteristics such as organic carbon abundance, trace element abundance, and mineralogical distribution. Quarry and core data also describe existing fracture planes (orientation, aperture, mineral fill, spacing, length) within the rock. These fracture data will be used to document and correlate changes or trends of fracturing to the microfacies identified within the rock. In addition to the previously defined microfacies, additional microfacies are emerging at the most distant column location. Fracture characteristics are expected to vary across microfacies boundaries within each column, as mechanical properties differ between microfacies.

Selected References

Brett, C.E., G.C. Baird, A.J. Bartholomew, M.K. DeSantis, and C.A. Ver Straeten, 2011, Sequence stratigraphy and a revised sea-level curve for the Middle Devonian of eastern North America: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 304/1, p. 21-53.

Droser, M.L., and D.J. Bottjer, 1986, A semiquantitative field classification of ichnofabric: Research method paper: Journal of Sedimentary Research, v. 56/4.

Karaca, C., 2012, Characterization of the Union Springs Formation, Finger Lakes Region, NY: an integrated high resolution facies, geochemical and sequence stratigraphical approach (MS thesis): Cornell University, 92 p.

Macquaker, J.H., and A.E. Adams, 2003, Maximizing information from fine-grained sedimentary rocks: an inclusive nomenclature for mudstones: Journal of Sedimentary Research, v. 73/5, p. 735-744.

Raiswell, R., 1976, The microbiological formation of carbonate concretions in the Upper Lias of NE England: Chem. Geol., v. 18, p. 227--244.

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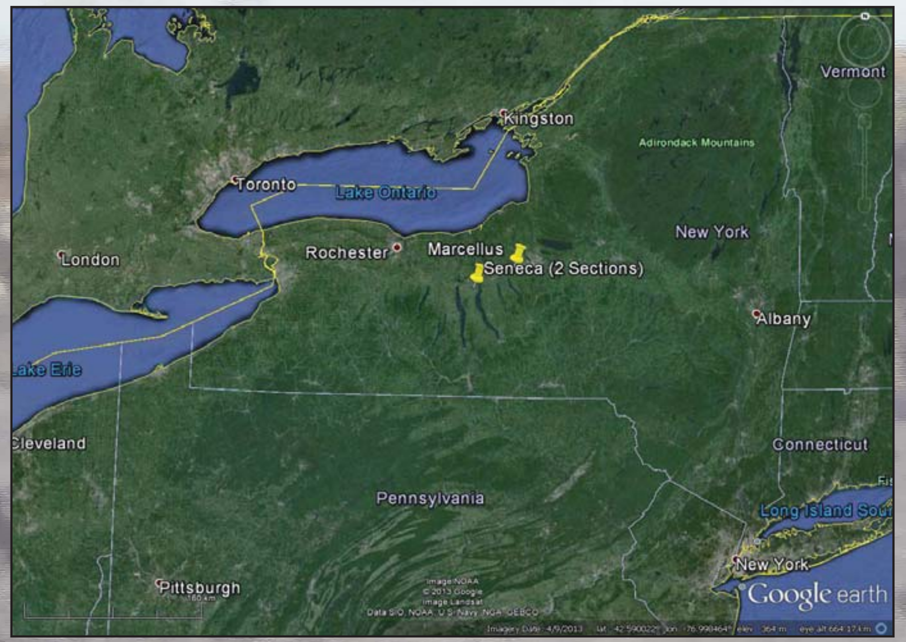
Characterizing Variability In the Union Springs

What degree of variability exists across length scales within a particular formation? In this study, we describe the types of changes observed amongst three Union Springs stratigraphic columns in upstate New York. Fresh quarry outcrop was analyzed, and the rocks were assigned within a microfacies framework, then compared to a "reference column" studied by Karaca (2012).

The three lithofacies described include a limestone member, a thicker, organic-rich mudstone member, and a member containing pervasive calcite concretions. The arrangement of these larger-scale lithofacies is constant for each column, although when examined in finer detail and classified into microfacies, differences begin to emerge between locations.

Above: Quarry exposure of Union Springs Formation studied on North Wall of Seneca Stone Quarry



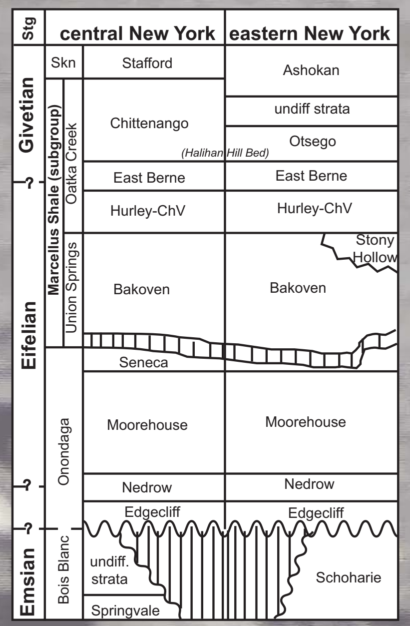
Above: Yellow pins indicate regional position of the study area in upstate New York. Two Union Springs exposures were examined near Seneca Falls, NY, as well as one near Marcellus, NY.

Introduction

This study examines change within the Marcellus Shale across upstate New York, with the goal of qualifying the degree of change which is to be expected as one moves between points in the basin.

Studied columns are composed of freshly-exposed quarry outcrop, and are demarcated by yellow pins in the map at left. The entirety of the Bakoven member of the Union Springs Formation (Lower Marcellus Subgroup) was studied at each location.

Columns were located at distances of 160 m, 600 m, and 38 km from the reference column, and roughly trended along the formation strike. Column thickness ranged between 3.22-3.63 m, with the thinnest column being located at the Eastern edge of the study area.



Above: Stratigraphic setting of the Marcellus Subgroup. This study targets the entirety of the Bakoven member of the Union Springs. Adapted from Brett et al (2011)

Methods

Field geology techniques along with thin section analysis and scanning electron microscopy were used to inform microfacies assignment. Quarry studies included documentation of sedimentological data as well as fracture fill and orientation. Rock properties were also recorded using nanoCT technology, as well as geochemical trace metal analysis (ongoing) and the description of fossil species distribution and abundance (ongoing).

Microfacies were named following the nomenclature proposed by Macquaker and Adams (2003):
All rocks with ≥50% (by volume) of constituent particles ≤63 microns in diameter = "Mudstone"
Compositional Modifiers are added to the name to provide additional description:

>90% [component]
"Dominated"

50% < [component] < 90%
"Rich"

10%< [component] < 50%
"Bearing"

For the limestone lithofacies, identified near the base of each section, the Dunham (1962) classification was used to provide textural desciption

Microfacies Interpretation

Three broad lithofacies were identified by compositional, textural, and positional features within the three columns, and thirteen lithofacies were assigned within these larger groups to describe the higher-order changes within the formation.

Lithofacies	*#*	*Microfacies*	*Bioturb Ind.*	*Taxa**	*Abundance (1-3)**
Limestone	*2*	*Dacryoconarid Wackestone*	4	1	3
	3	*Dacryoconarid Packstone*	5	1, 2, 6, 7	3
	4	*Clay and Organic Matter Bearing Dacryoconarid Wackestone*	4	7	3
	5	*Striped Mudstone*	2	1	3
Organic Rich Mudstone	*1*	*Clay and Organic Rich Dolomite and Quartz Bearing Mudstone*	2	1	1
	6	*Clay and Organic Rich Laminated Algal Mudstone*	1	1, 4	2
	7	*Clay and Organic Rich Dacryoconarid Bearing Laminated Mudstone*	1	1	1
	8	*Clay and Organic Rich Fossil Bearing Laminated Mudstone*	2	1, 3, 4, 5	3
	9	*Clay and Organic Rich Silt Bearing Laminated Mudstone*	2	1	2
Concretionary Mudstone	*10*	*Algae Bearing Calcareous Concretion*	1	7	2
	11	*Algae and Dacryoconarid Bearing Calcareous Concretion*	1	1	1
	12	*Clay and Organic Rich Calcareous Cement Bearing Mudstone*	3	1	2
	13	*Dacryoconarid and Algae Rich Zoned Calcareous Concretion*	1	1	2

***Key:**
Bioturbation Index:
1: none
6: bedding homogenized
(Droser,Bottjer)

Taxa:
1. Dacryoconarida
2. *Cherryvalleyrostrum*
3. *Eumetabolotoechia*
4. *Ptychodesma*
5. *Lingula*
6. *Fish bones/debris*
7. *Tasmanites*

Abundance:
1: rare
3: very abundant
(from bed plane analysis and thin sxn

Special Thanks to Claire Behar for fossil abundance data

The Limestone lithofacies is characterized by a series of interbedded packstone and wackestone layers, moderate bioturbation, and lower organic carbon content than the other facies in the column (generally <3% TOC).

The sample at left is an example of Microfacies 3: *Dacryoconarid Packstone*, collected from the South wall of the Seneca Stone Quarry near Seneca Falls, NY.

The Organic Rich Mudstone lithofacies is primarily composed of thinly bedded clay and organic matter in parallel continuous laminations. Isolated beds with high concentrations of calcareous material, generally in the form of compacted shell debris, occur frequently.

The sample at left is an example of Microfacies 8: *Clay and Organic Rich Fossil Bearing Laminated Mudstone.* The typical thin interbedding of organic rich laminae and brachiopod valve-rich horizons is observed here near the bottom of the sample.

The Concretionary Mudstone facies group includes moderately organic rich mudstones, as well as mudstones with varying degrees of calcareous cementation or concretions. Concretions may be ellipsiodal in nature, or appear to be continuous within beds. Concretions themselves often displace the beds which surround them.

The sample at left is a *Dacryoconarid and Algae Rich Zoned Calcareous Concretion* (Microfacies 13), displacing surrounding organic rich silt bearing mudstone.

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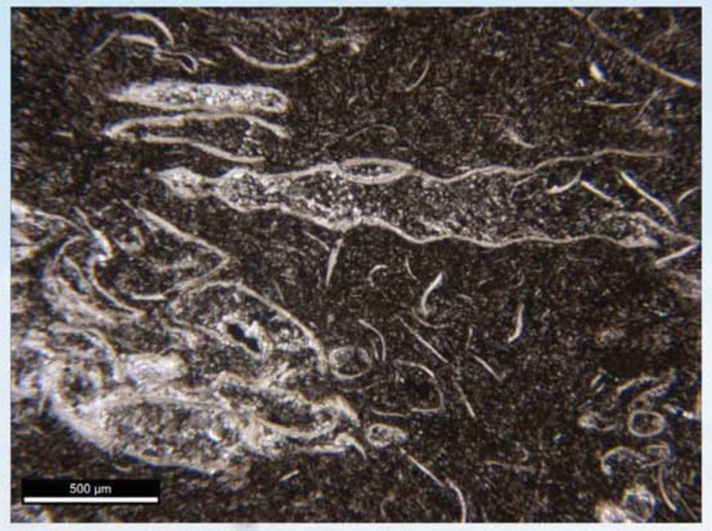
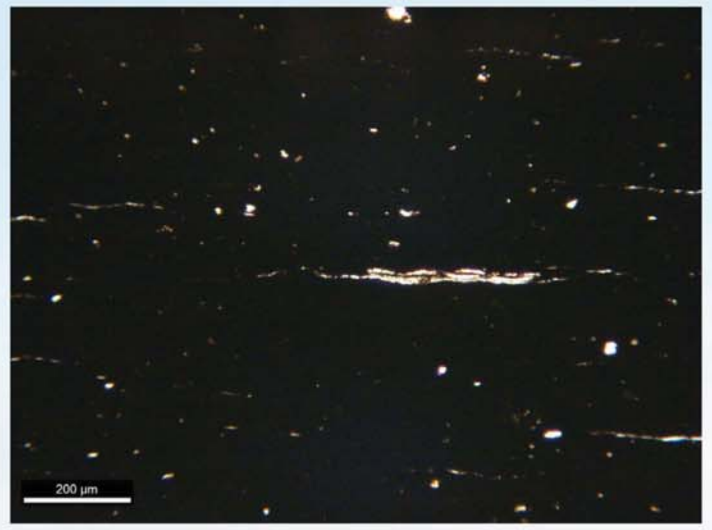
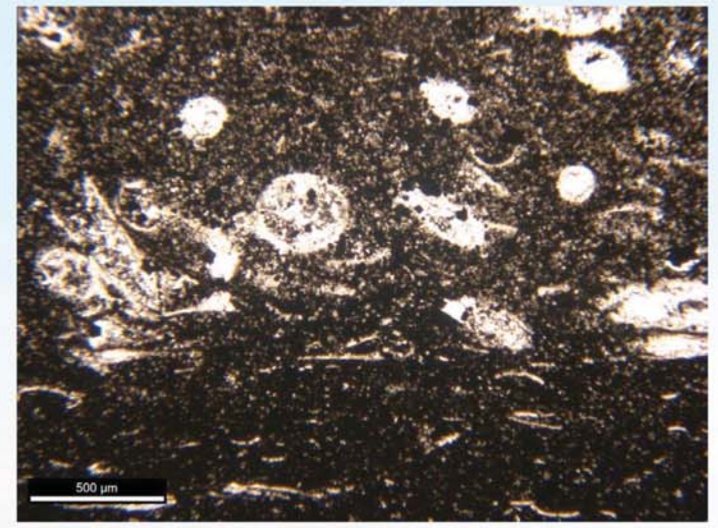
Examining the Marcellus in Thin Section



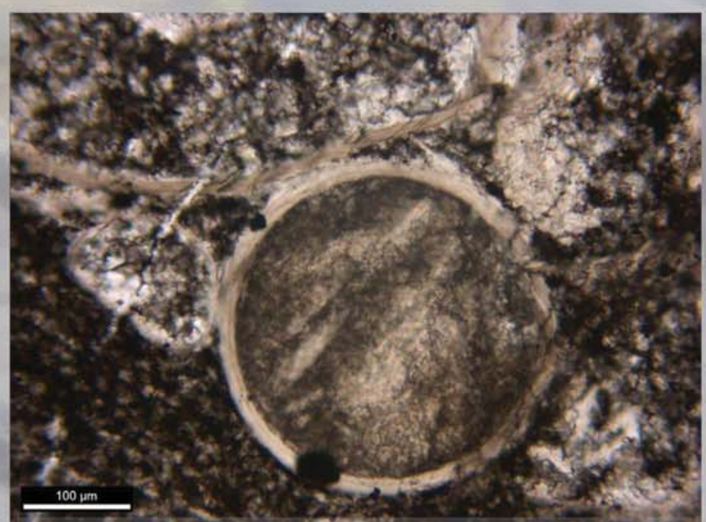
Above: Dacryoconarid Packstone. Cross-sectional intact shell material in a clay-organic matrix. 0.9% TOC. PPL. 500 micron scale bar



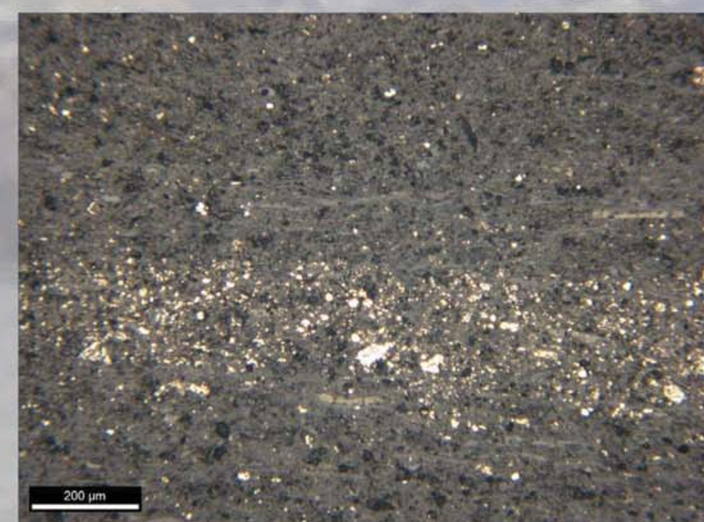
Above: Organic Rich Mudstone lithofacies. Largely opaque, and showing evidence of significant compaction. 12.6 % TOC. PPL. 200 micron scale bar.



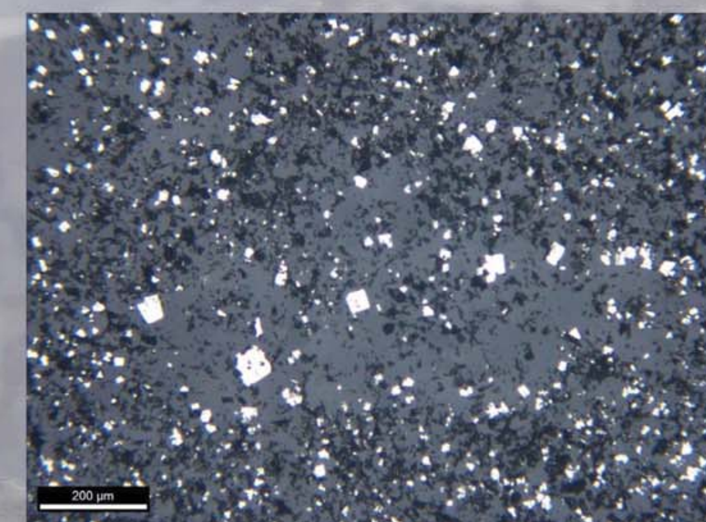
Above: Dacryoconarid and Algae Rich Zoned Calcareous Concretion microfacies. Zoning evident between fully cemented region, and bedded, compacted clay rich matrix. PPL. 500 micron scale bar



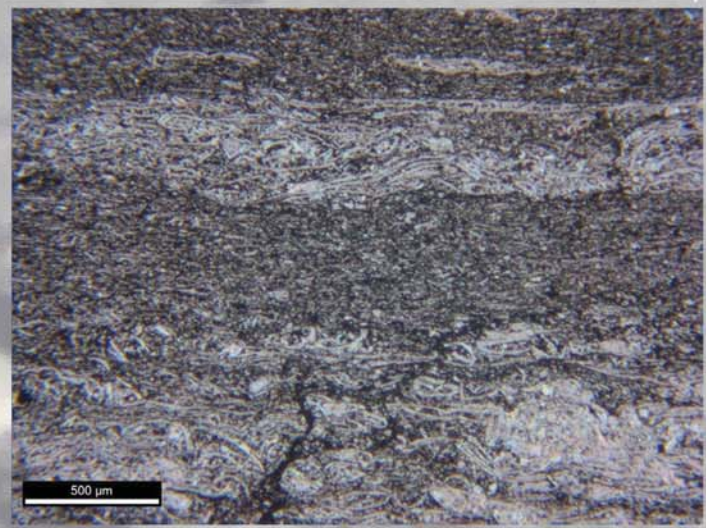
Above: Transverse section of a partially pyritized dacryoconarid shell with calcite fill. Dacryoconarid Packstone microfacies. PPL. 100 micron scale bar



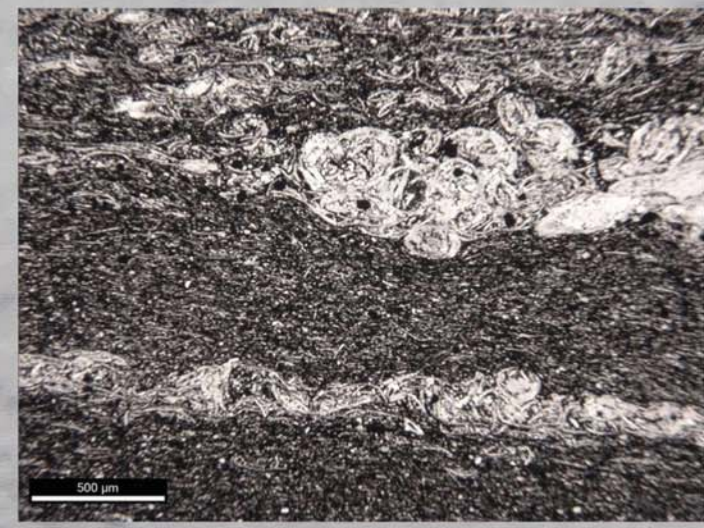
Above: Organic Rich Mudstone with pyrite lamination composed primarily of framboids. Sparse chalcopyrite is also visible. Reflected light. 200 micron scale bar.



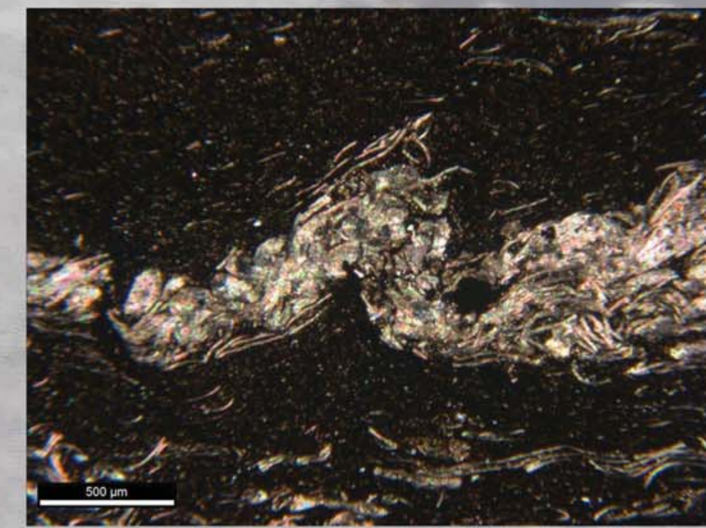
Above: Calcareous concretion with widely distributed euhedral pyrite. Concretions have been interpreted as the result of microbial oxidation processes in an anoxic environment. Reflected light. 200 micron scale bar.



Above: Striped Mudstone microfacies. Parallel, alternating interbeds of clay and shell material are crosscut here by a vein of organic matter. 8.2% TOC. PPL. 500 micron scale bar.



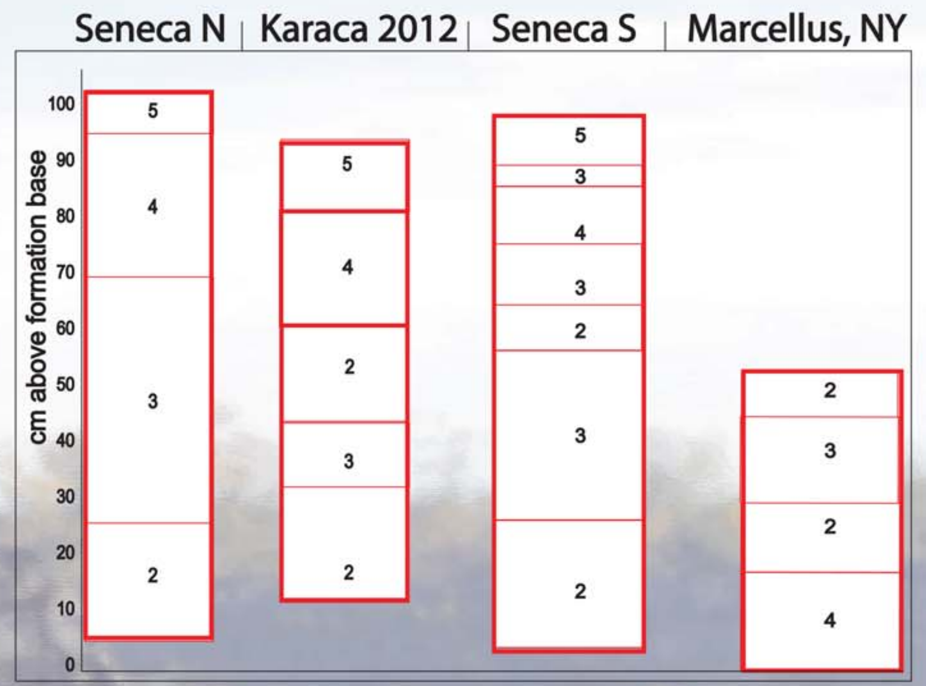
Above: Striped Mudstone microfacies. Small scale hummocky cross-stratification and graded clay beds suggest this facies may represent storm activity. 500 micron scale bar.



Above: Load structure indicative oi soft-sediment deformation, in organic rich mud-stone lithofacies. 10.4% TOC. PPL. 500 micron scale bar.

Comparing Microfacies Distribution and Abundance Across the Basin

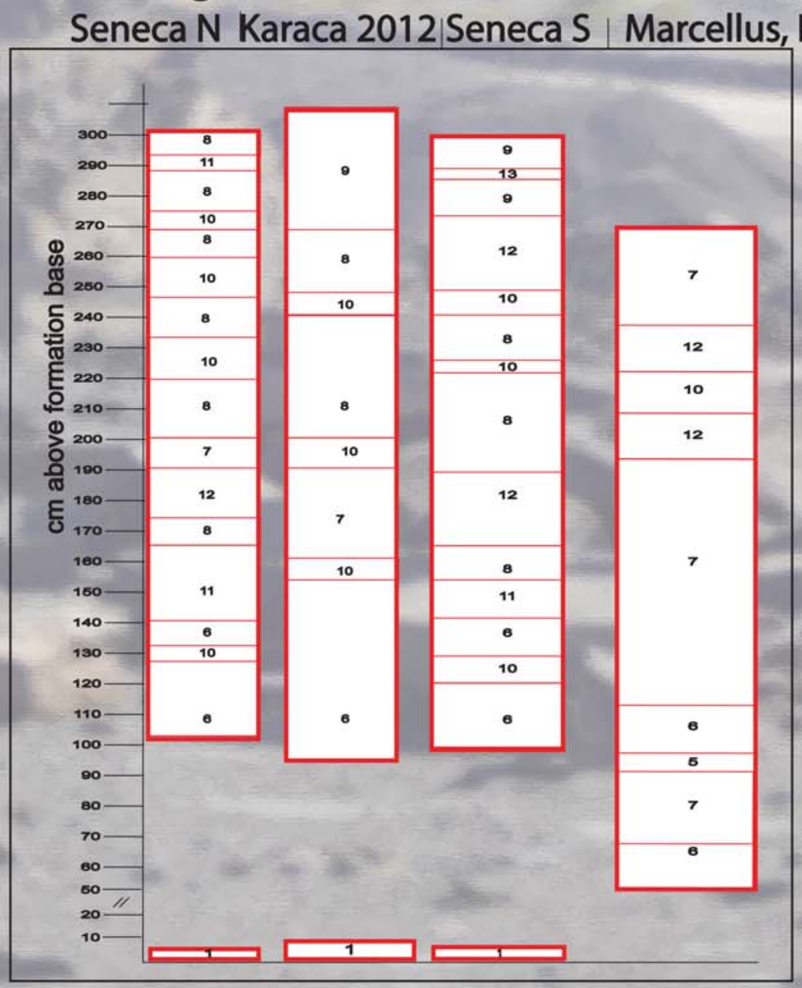
Limestone Facies



The Limestone lithofacies is a series of significantly bioturbated, fossil-bearing wackestones and packstones, and appears near the base of the Union Springs in each location. It never appears more than 7 cm from the basal contact. In the Seneca columns [including Karaca (2012)], this facies comprises about a fourth of the total section height. The Marcellus, NY limestone facies is equally fossil bearing and bioturbated (possibly more), however significantly less of the section contains it. This may be a result of basin position relative to sediment source and/or to paleobathymetry.

Seneca North: 98/360 cm = 27.2 %
Karaca (2012): 90/361 = 24.9 %
Seneca South: 94/363 = 25.9 %
Marcellus: 53/322 = 16.5 %

Organic Rich Mudstone Facies



The Organic Rich Mudstone lithofacies is the most dominant facies in each location. It is almost universally enriched in organic matter, and contains numerous periodic fossil-enriched beds. Pyritization of burrows and fossil shell debris has been observed, as well as large euhedral crystals as large as 15 mm. Laminations are typically spaced on the order of 1 mm, although fissility is certainly not constant between columns (notably in Marcellus, which is much less fissile than the other columns). There are occasional rippled beds and soft-sediment deformational structures which may be indicative of storm deposition.

Seneca North: 202/360 cm = 56.1 %
Karaca (2012): 226/361 = 62.6 %
Seneca South: 204/363 = 56.2 %
Marcellus: 216/322 = 67.1 %

Concretionary Mudstone Facies

The Concretionary Mudstone lithofacies marks a transition from black mudstones with occasionally-cemented layers/concretions, to black/grey mudstones which commonly host calcite concretions. These concretions have been explained to result from anaerobic bacterial processes occurring during the earliest diagenetic periods. These concretions have slightly variable composition between microfacies but all show significantly less evidneces of compaction, implying early concretion growth (Raiswell 1976)

Seneca North: 60/360 cm = 16.7 %
Karaca (2012): 45/361 = 12.5 %
Seneca South: 65/363 = 17.9 %
Marcellus: 53/322 = 16.5 %

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