PSThe Middle Devonian Marcellus Shale - a Record of Eustacy and Basin Dynamics*

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Abstract

The stratigraphy of the Middle Devonian Marcellus Shale of the Appalachian Basin reflects the interplay of Acadian-related flexural loading of the Laurentian craton and two rapid sea level rises. Accumulation of the Union Springs Shale, the lower unit of the Marcellus Shale, over the variably eroded Onondaga Limestone was coincident with a middle Eifelian rise in sea level (T-R Cycle 1d) and the onset of Tectophase II of the Acadian Orogeny. The result of both events was a thin, highly radioactive, pyritiferous condensed interval at the base of the Union Springs. Further, isopach patterns reveal that the Union Springs was completely eroded along a NE-SW-trending region of western New York and western Pennsylvania, a likely consequence of development of a tectonic welt or forebulge induced by thrust loading. The overlying Cherry Valley (Purcell) Limestone likely reflects a brief stabilization of sea level. The Cherry Valley displays an isopach pattern similar to that of the underlying Union Springs Shale, suggesting that the tectonic welt was reactivated soon after accumulation of the carbonate sediment. Deposition of the organic-rich Oatka Creek Shale, the upper unit of the Marcellus Shale, reflects a late Eifelian eustatic rise in sea level (T-R Cycle 1e). This event, in tandem with continued load-induced subsidence, resulted in accumulation of a carbonaceous basal interval that passes upward into less organic-rich shale. The Oatka Creek Shale, like the underlying units of the Marcellus Shale, was eroded along a NW-SE-oriented axis in western New York. However, the locus of erosion had shifted somewhat to the east, perhaps recording a brief period of tectonic relaxation at the end of Marcellus time.

References

- Brown, L.F., Jr., R.G. Loucks, and R.H. Trevino, 2005, Site-specific sequence-stratigraphic section benchmark charts are key to regional chronostratigraphic systems tract analysis in growth-faulted basins: American Association of Petroleum Geologists Bulletin, v. 89, p. 715-724.
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Johnson, J.G., G. Klapper, and C.A. Sandberg, 1985, Devonian eustatic fluctuations in Euramerica: GSA Bulletin, v. 96, p. 567-587.

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THE MIDDLE DEVONIAN MARCELLUS SHALE – A RECORD OF EUSTACY AND BASIN DYNAMICS

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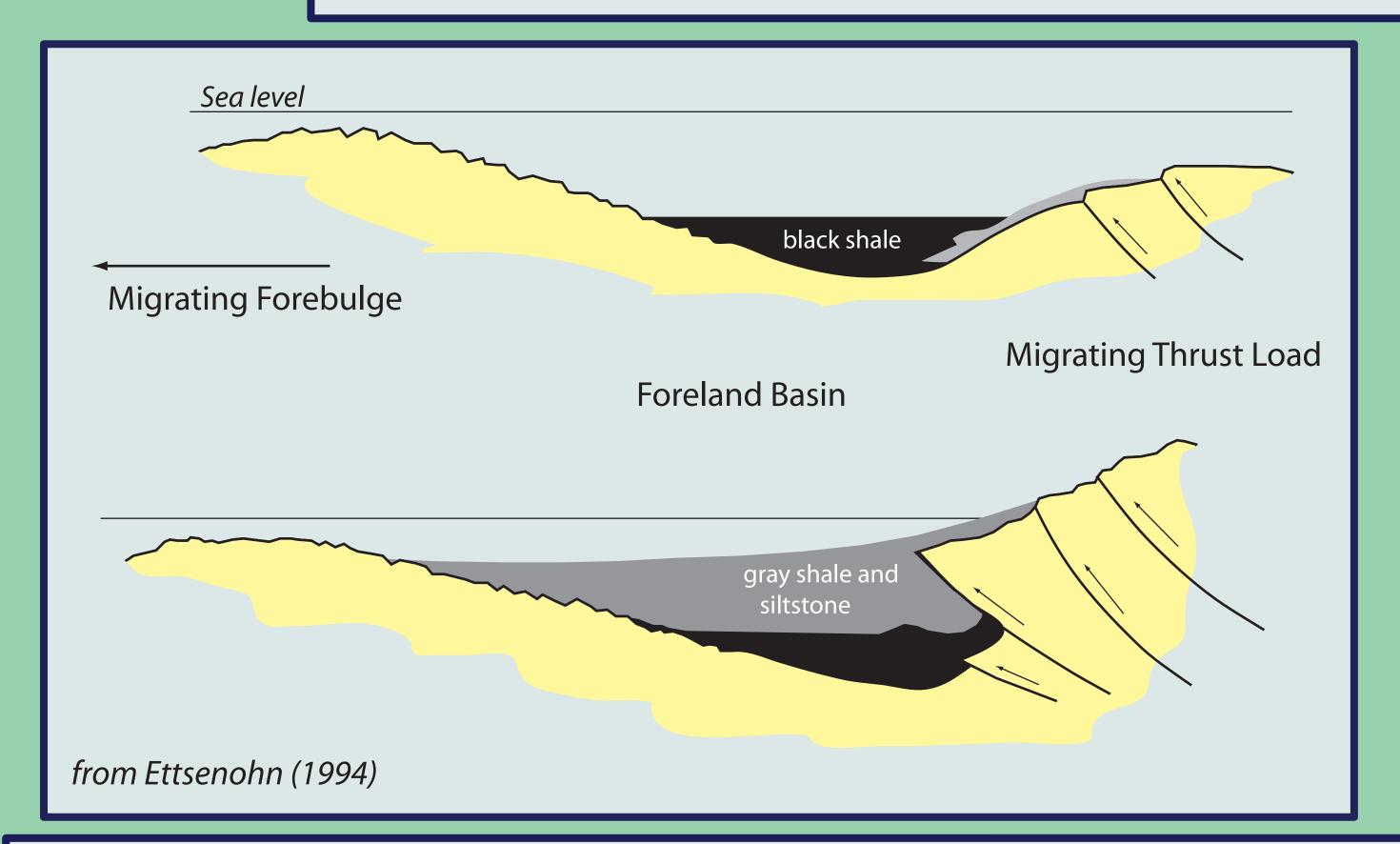
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ABSTRACT

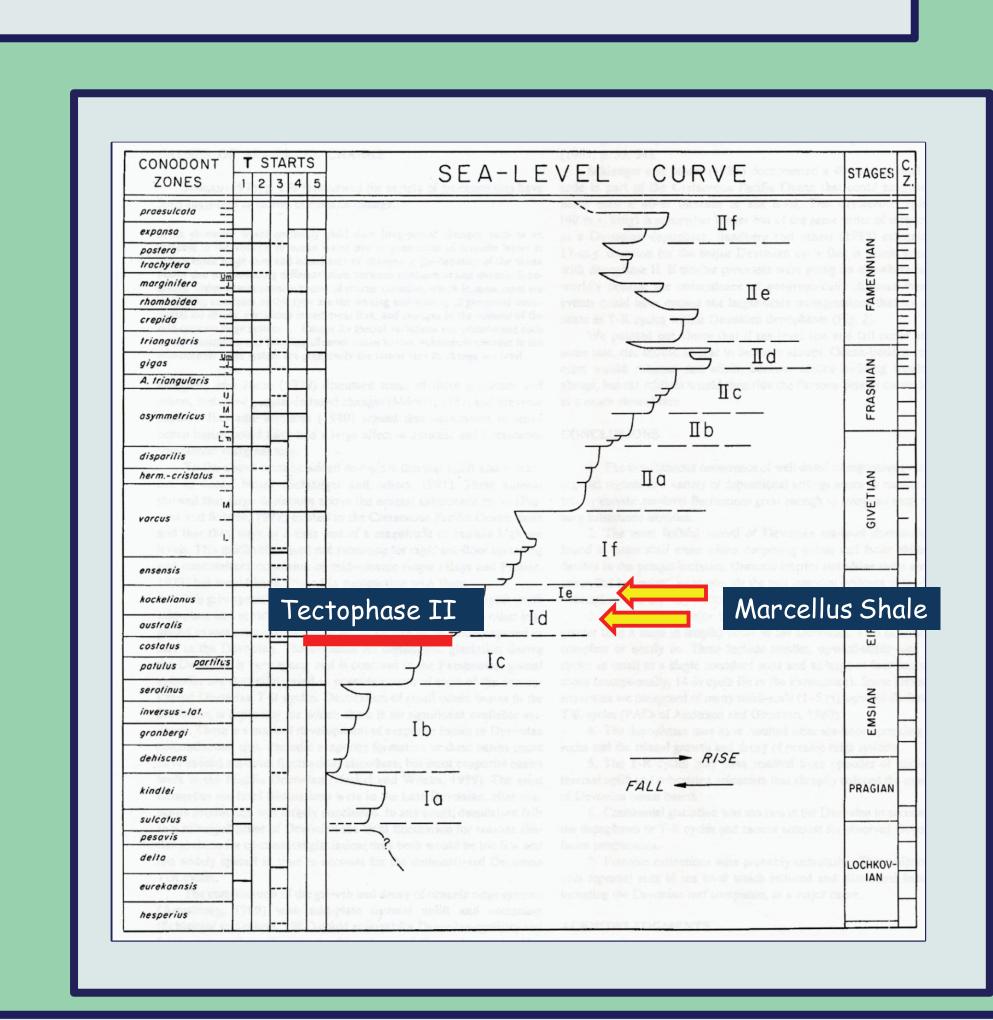
The stratigraphy of the Middle Devonian Marcellus Shale of the Appalachian Basin reflects the interplay of Acadian-related flexural loading of the Laurentian craton and two rapid sea level rises. Accumulation of the Union Springs Shale, the lower unit of the Marcellus Shale, over the variably eroded Onondaga Limestone was coincident with a Middle Eifelian rise in sea level (T-R Cycle 1d) and the onset of Tectophase II of the Acadian Orogeny. The result of both events was a thin, highly radioactive, pyritiferous condensed interval at the base of the Union Springs. Further, isopach patterns reveal that the Union Springs was completely eroded along a NE-SW-trending region of western New York and western Pennsylvania, a likely consequence of development of a tectonic welt or forebulge induced by thrust loading. The overlying Cherry Valley (Purcell) Limestone likely reflects a brief stabilization of sea level. The Cherry Valley displays an isopach pattern similar to that of the underlying Union Springs Shale, suggesting that the tectonic welt was reactivated soon after accumulation of the carbonate sediment. Deposition of the organic-rich Oatka Creek Shale, the upper unit of the Marcellus Shale, reflects a Late Eifelian eustatic rise in sea level (T-R Cycle 1e). This event, in tandem with continued load-induced subsidence, resulted in accumulation of a carbonaceous basal interval that passes upward into less organic-rich shale. The Oatka Creek Shale, like the underlying units of the Marcellus Shale, was eroded along a NW-SE-oriented axis in western New York. However, the locus of erosion had shifted somewhat to the east, perhaps recording a brief period of tectonic relaxation at the end of Marcellus time.

INTRODUCTION

This paper presents results of an ongoing study of the subsurface stratigraphy of the Middle Devonian Marcellus Shale of the Appalachian Basin of western New York, northwestern Pennsylvania, northern West Virginia, western Maryland, and eastern Ohio. The principal goals of this work include (1) the documentation of the role of basin dynamics on sedimentation patterns of this unit and (2) the generation of a sequence stratigraphic framework of the Marcellus Shale.

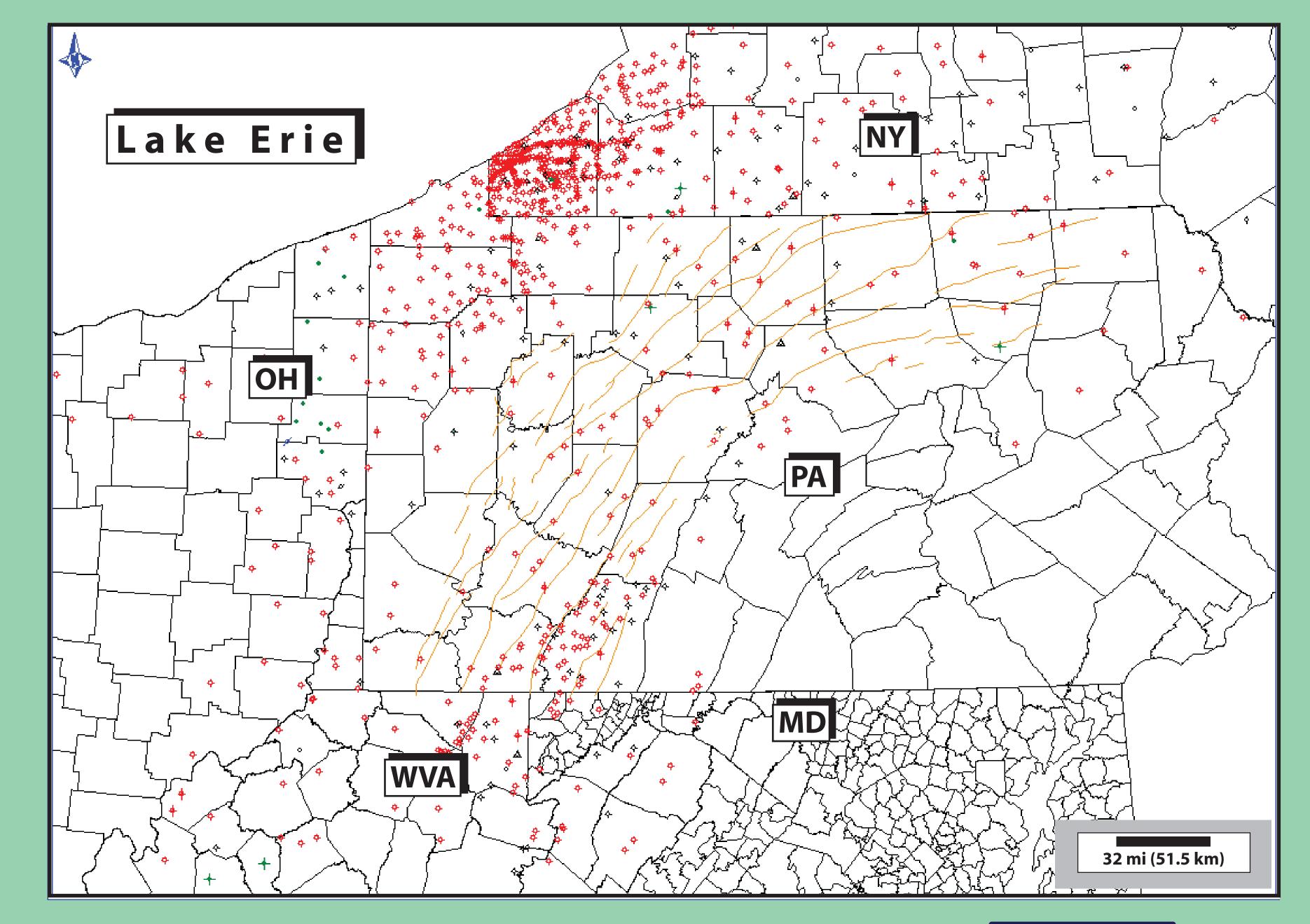


Ettensohn (1985, 1994) has demonstrated that major stratigraphic patterns of Middle and Upper Devonian black shale units, specifically their westward transgression over time, can be described in terms of four tectophases, each one defined by four stages, including (1) the inception of tectonism and consequent rapid subsidence of a foreland basin and consequent accumulation of black shale; (2) impending collision and associated regression and accumulation of gray shale and siltstone; (3) collision accompanied by widespread uplift and development of regional disconformities; and (4) tectonic quiescence and widespread accumulation of limestone in slowly transgressing seas.



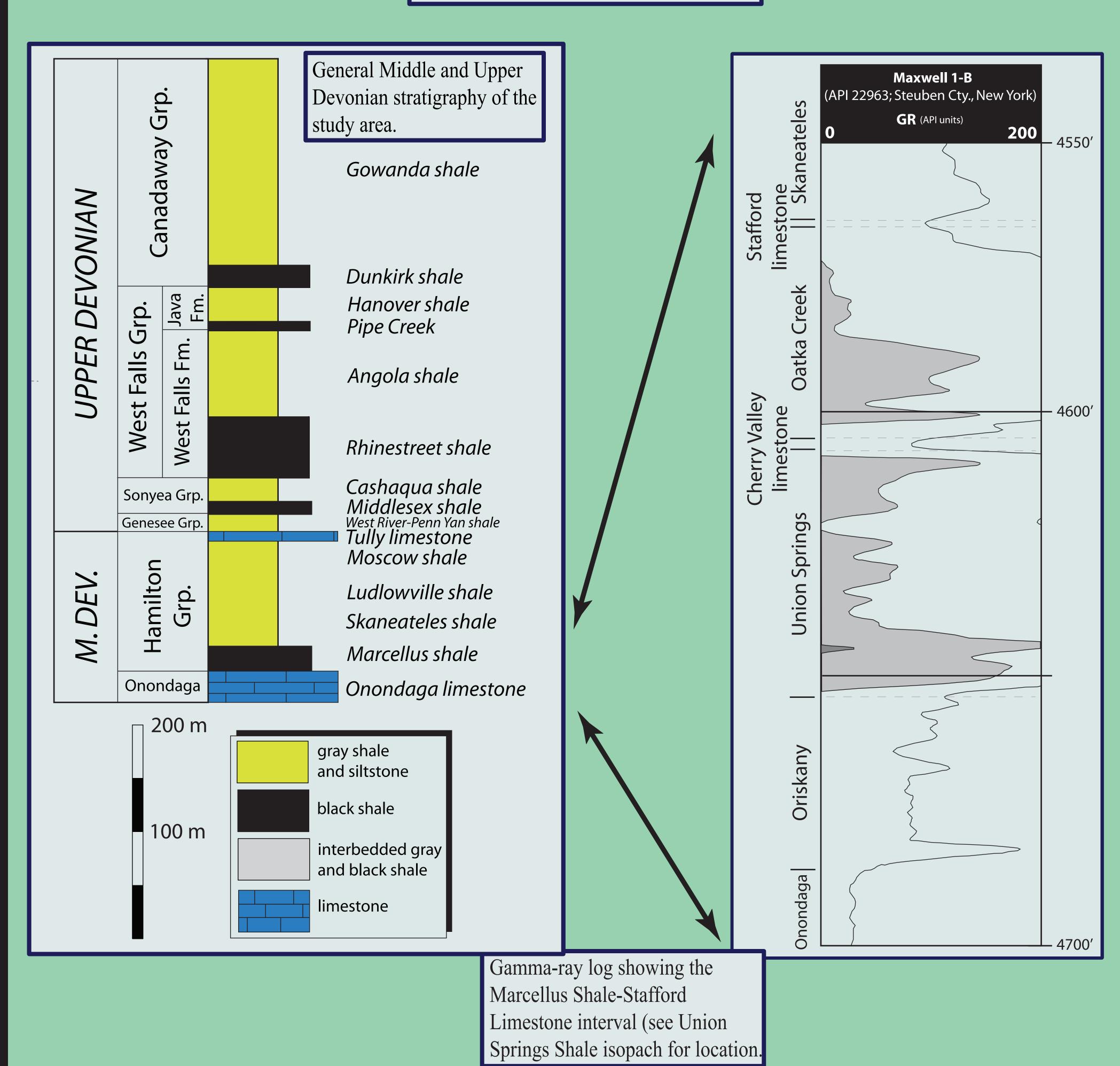
Accumulation of the Marcellus Shale corresponds with the onset of Tectophase II loading; however, the Marcellus also corresponds with two sea level rise events illustrated on the eustatic curve of Johnson et al. (1985).

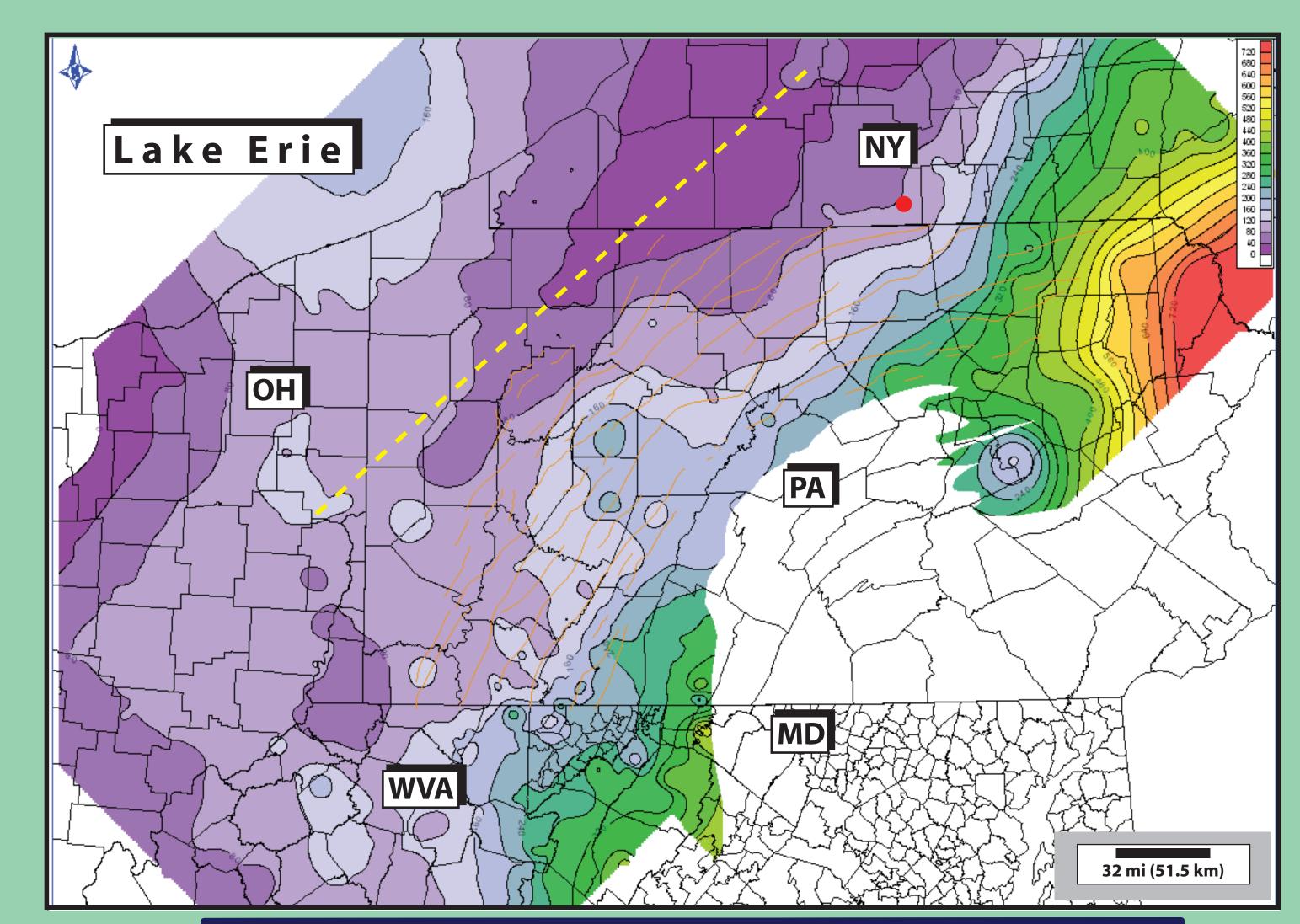
It is likely that both factors - tectonics (thrust load-induced subsidence) and global eustacy were active.



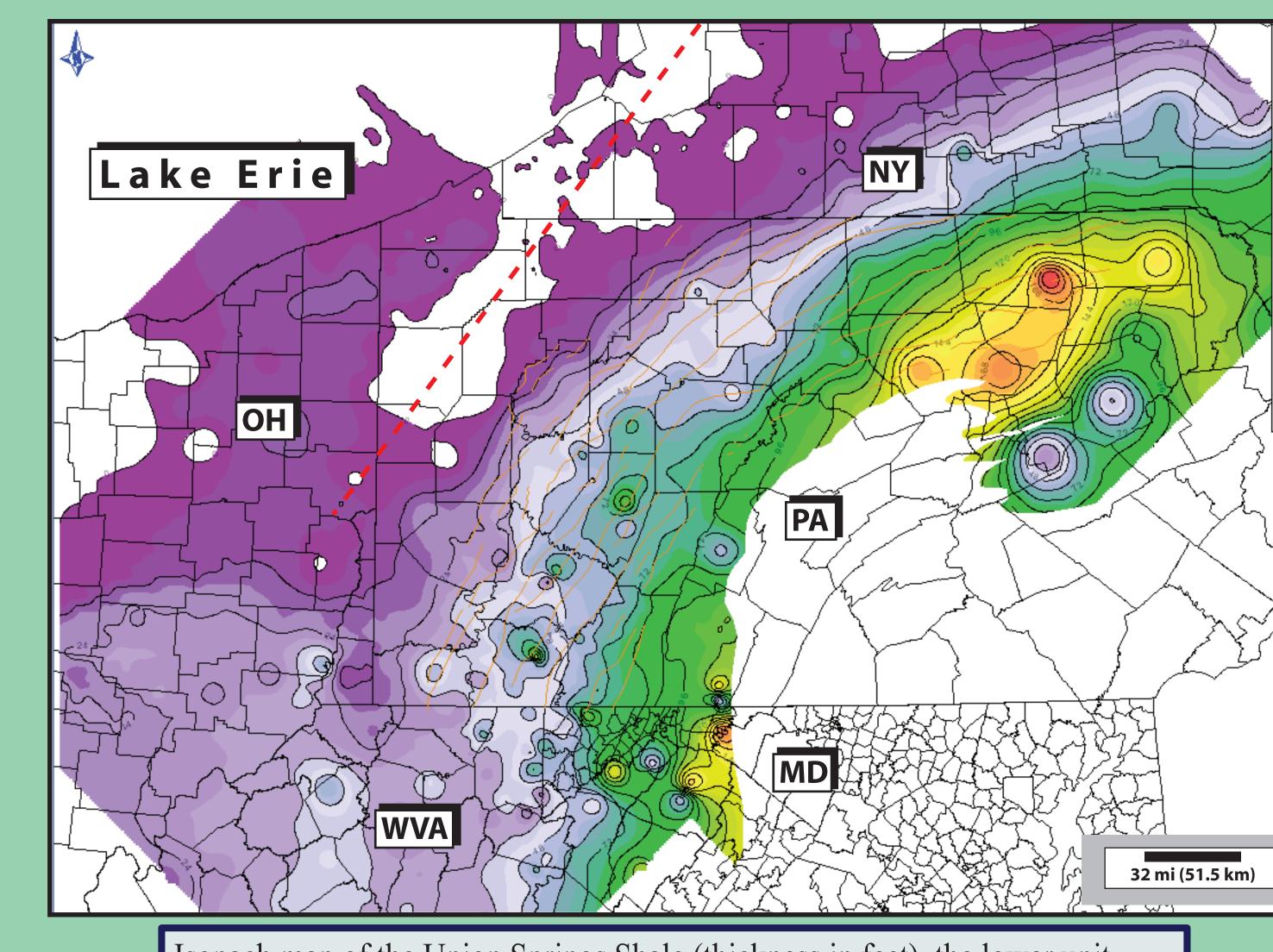
DATA

STRATIGRAPHY

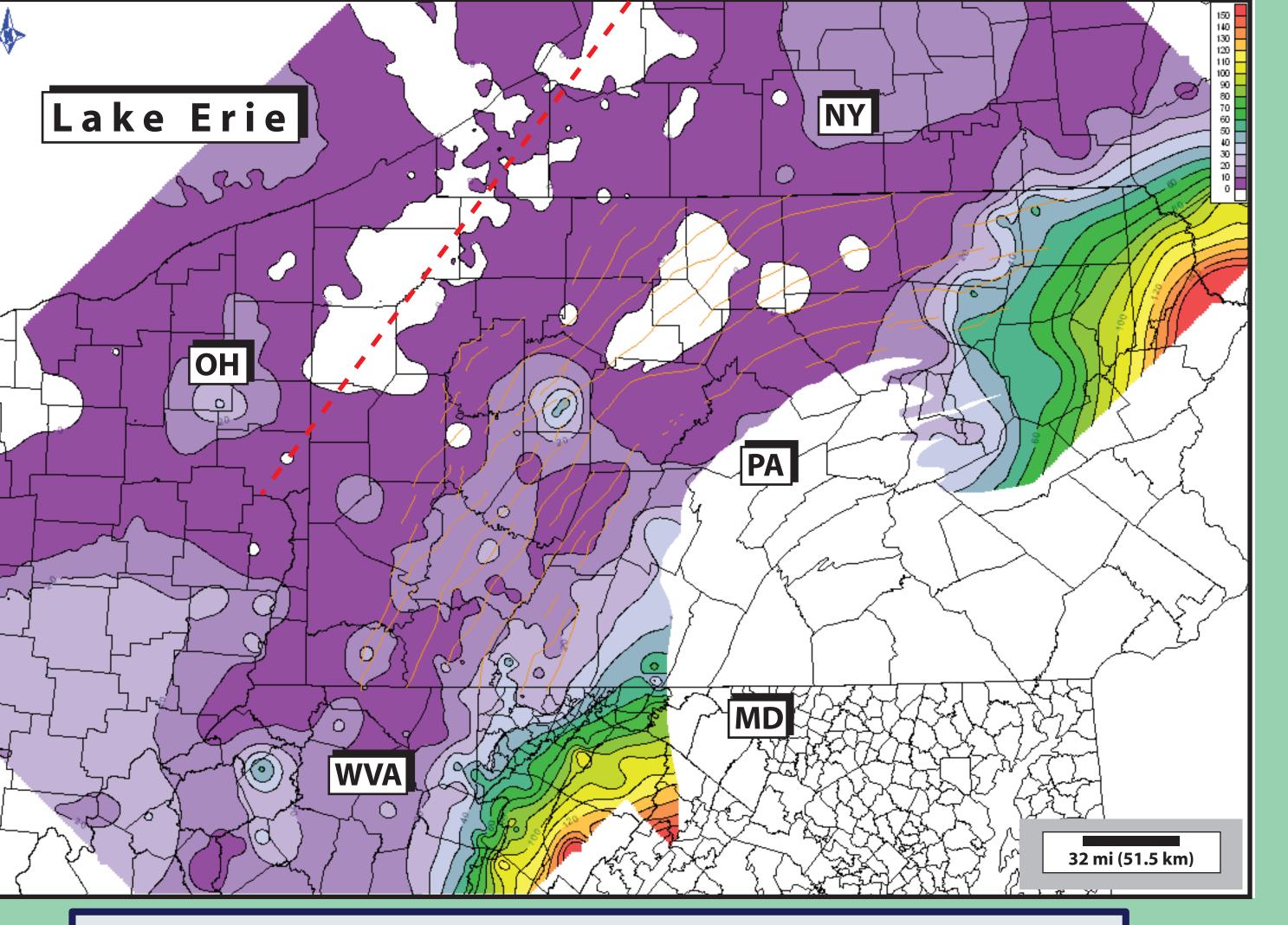




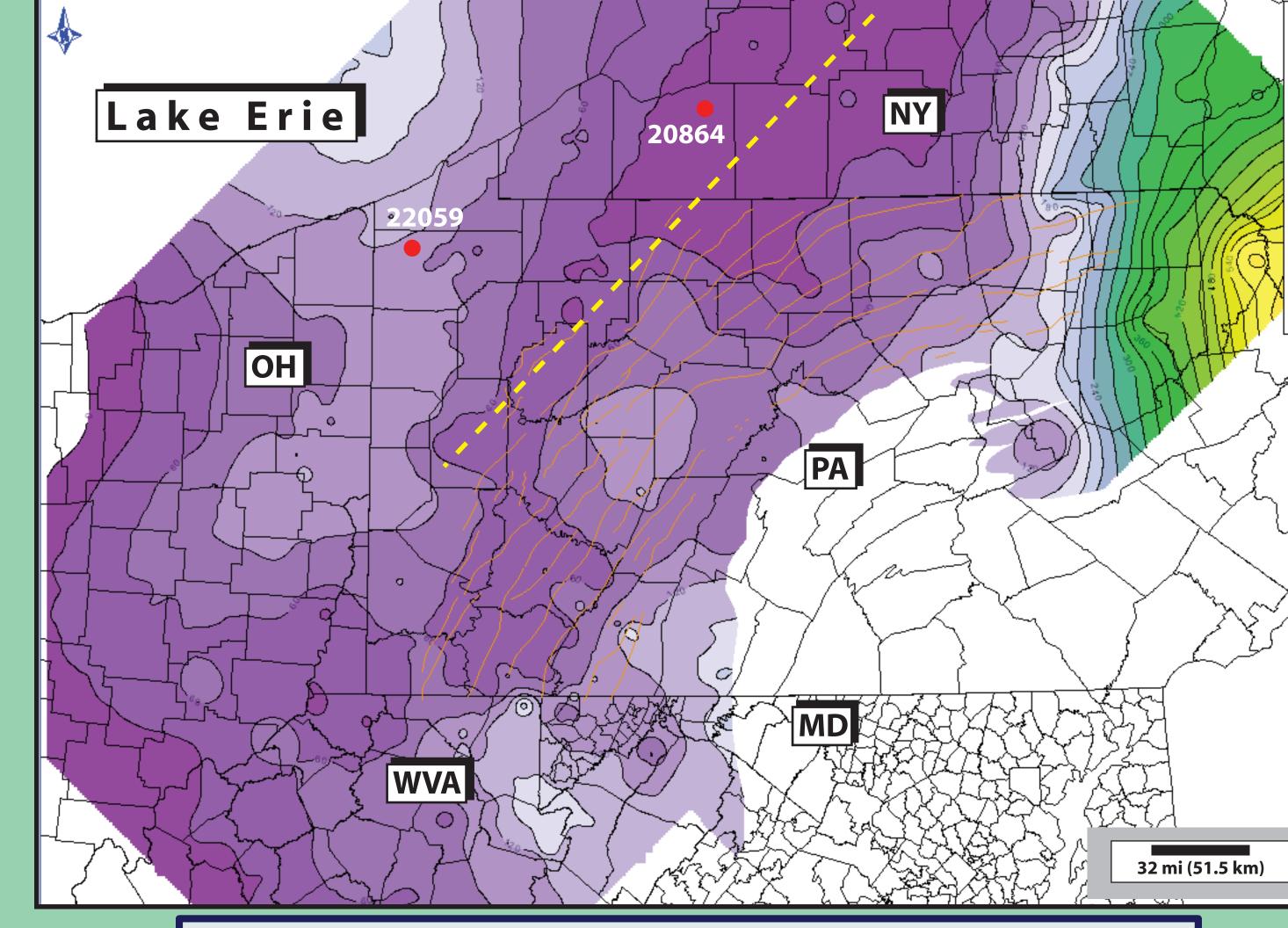
Isopach map of the total Marcellus Shale (thickness in feet). The red circle shows the location of well 22963; dashed yellow line denotes an axis of thinning of the Marcellus Shale.



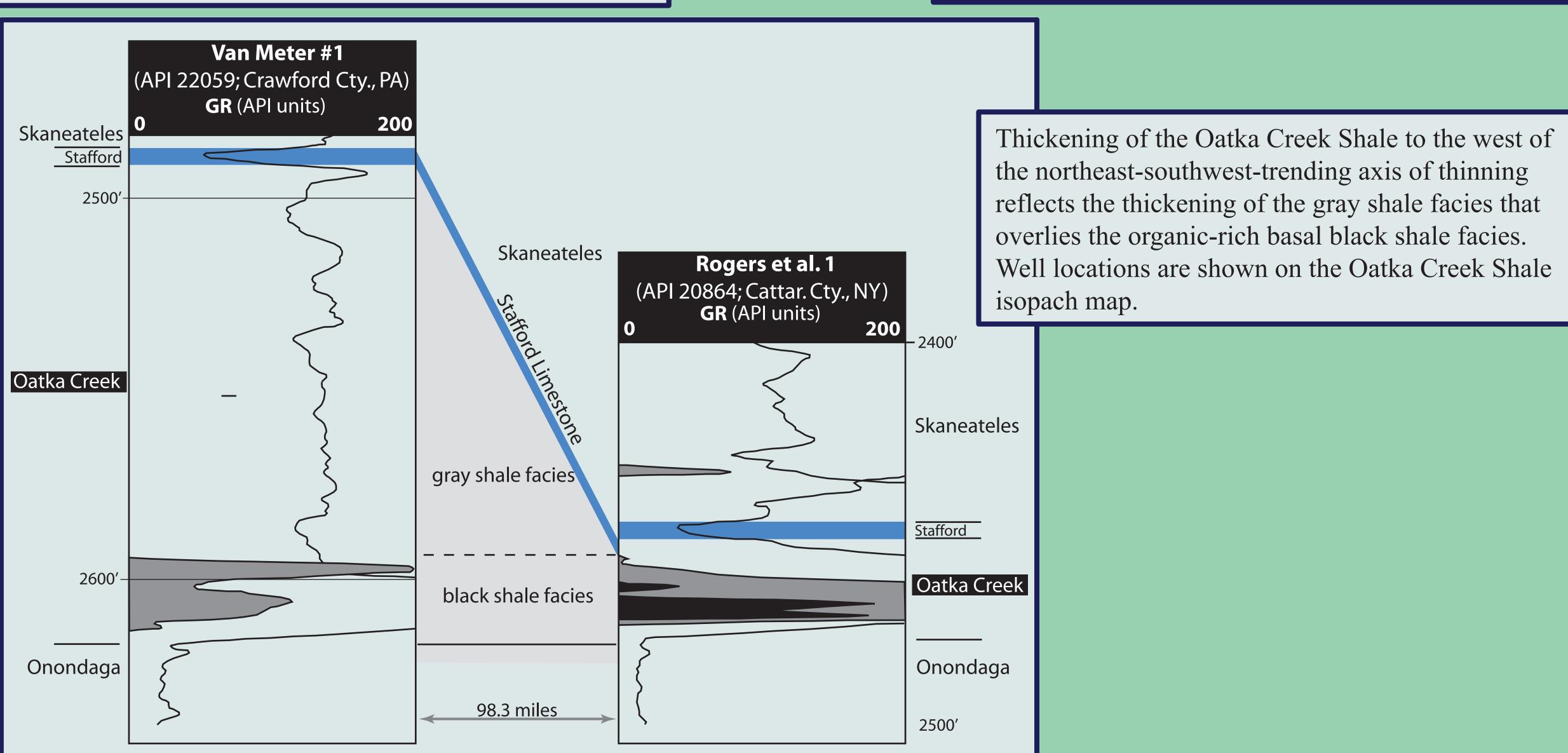
Isopach map of the Union Springs Shale (thickness in feet), the lower unit of the Marcellus Shale; dashed red line denotes the axis of minimum thickness of the Marcellus in the western New York - northwestern Pennsylavania region of the basin.

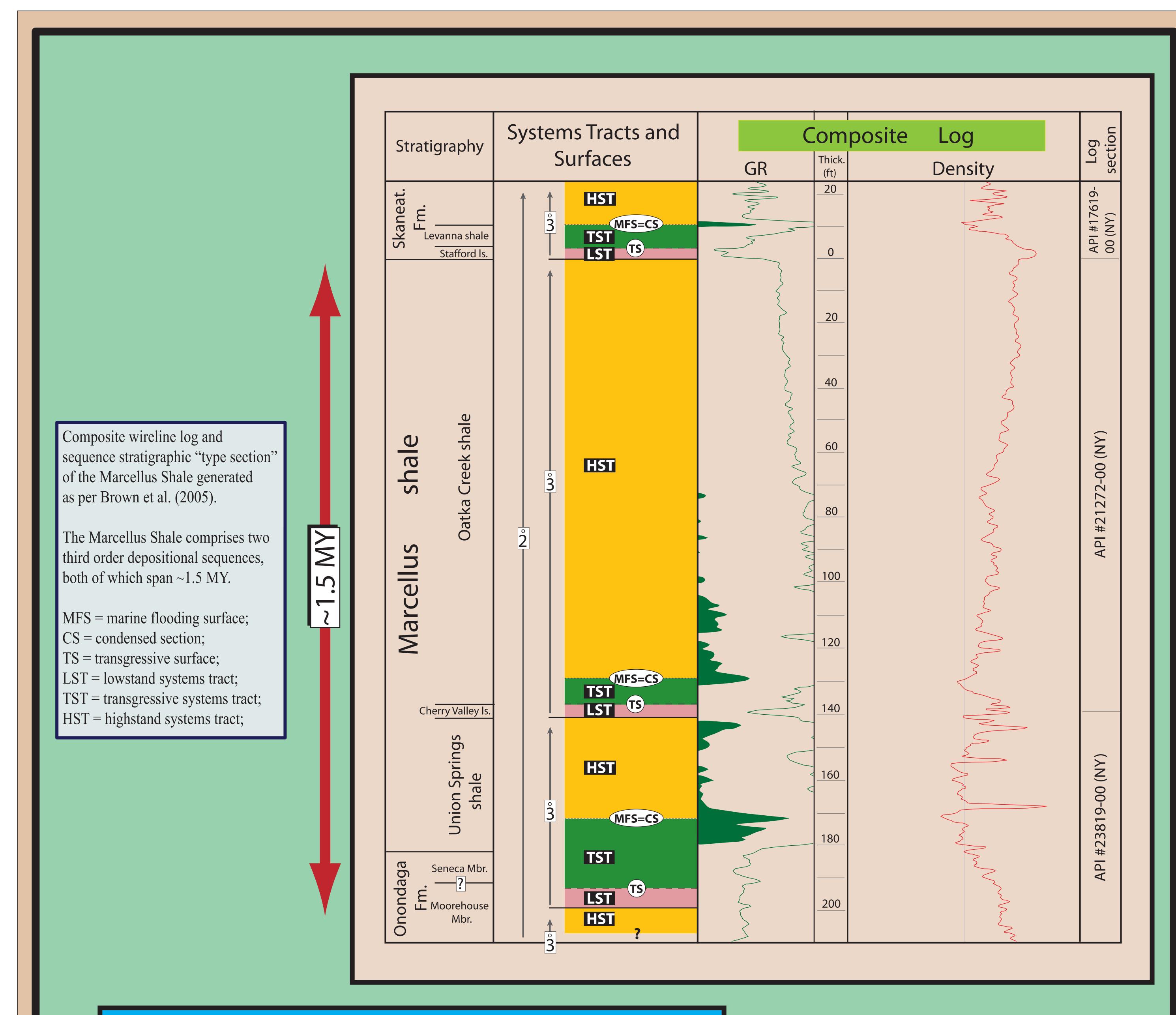


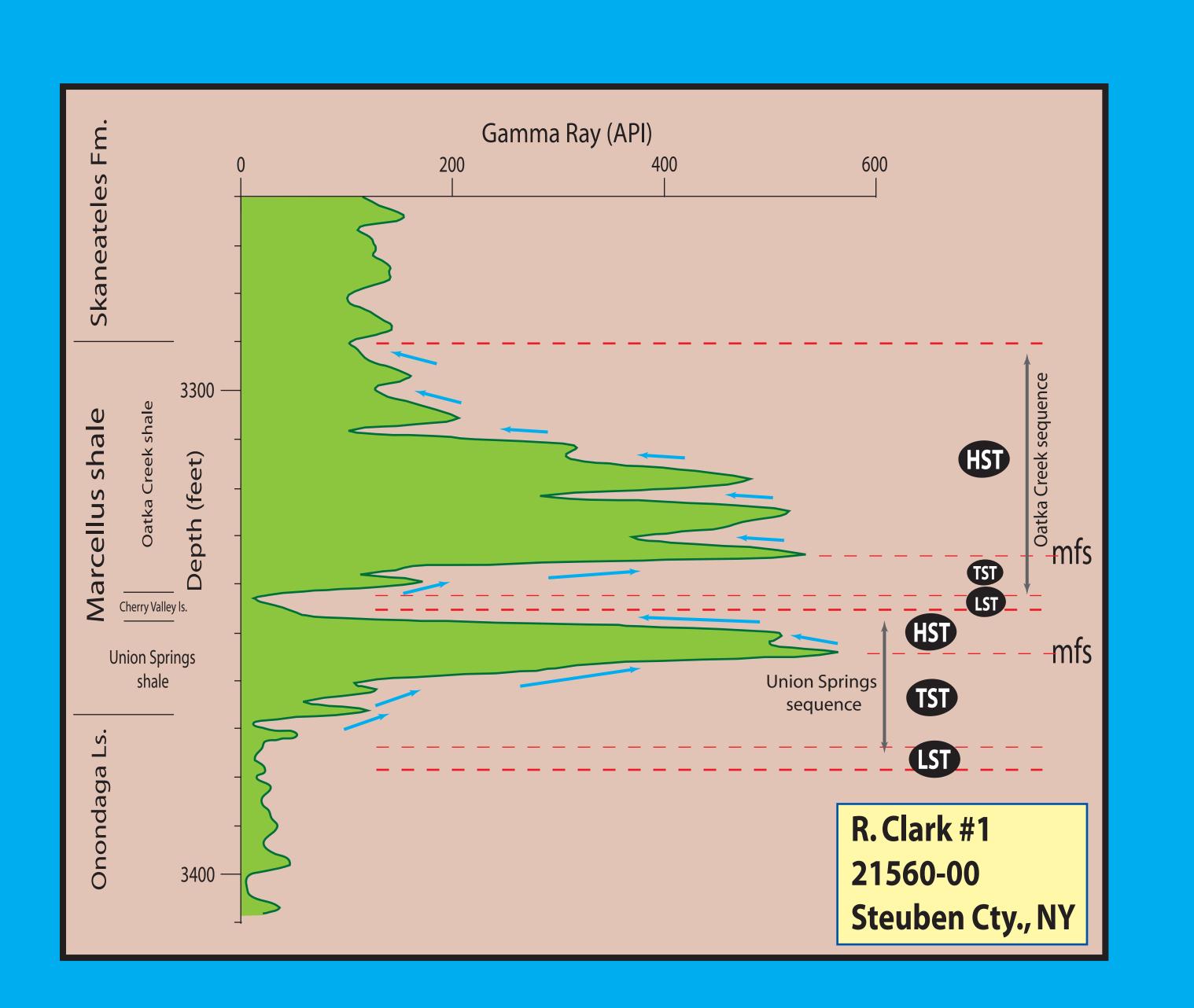
Isopach map of the Cherry Valley (Purcell) Limestone (thickness in feet), the middle unit of the Marcellus Shale; dashed red line denotes the axis of minimum thickness of the Marcellus Shale in the western New York - northwestern Pennsylavania region of the basin.



Isopach map of the Oatka Creek Shale (thickness in feet), the upper unit of the Marcellus Shale. The red circles denote the locations of wells 22059 and 20864; note the thinning of the Oatka Creek Shale to the east and west of the axis of thinning (dashed yellow line).

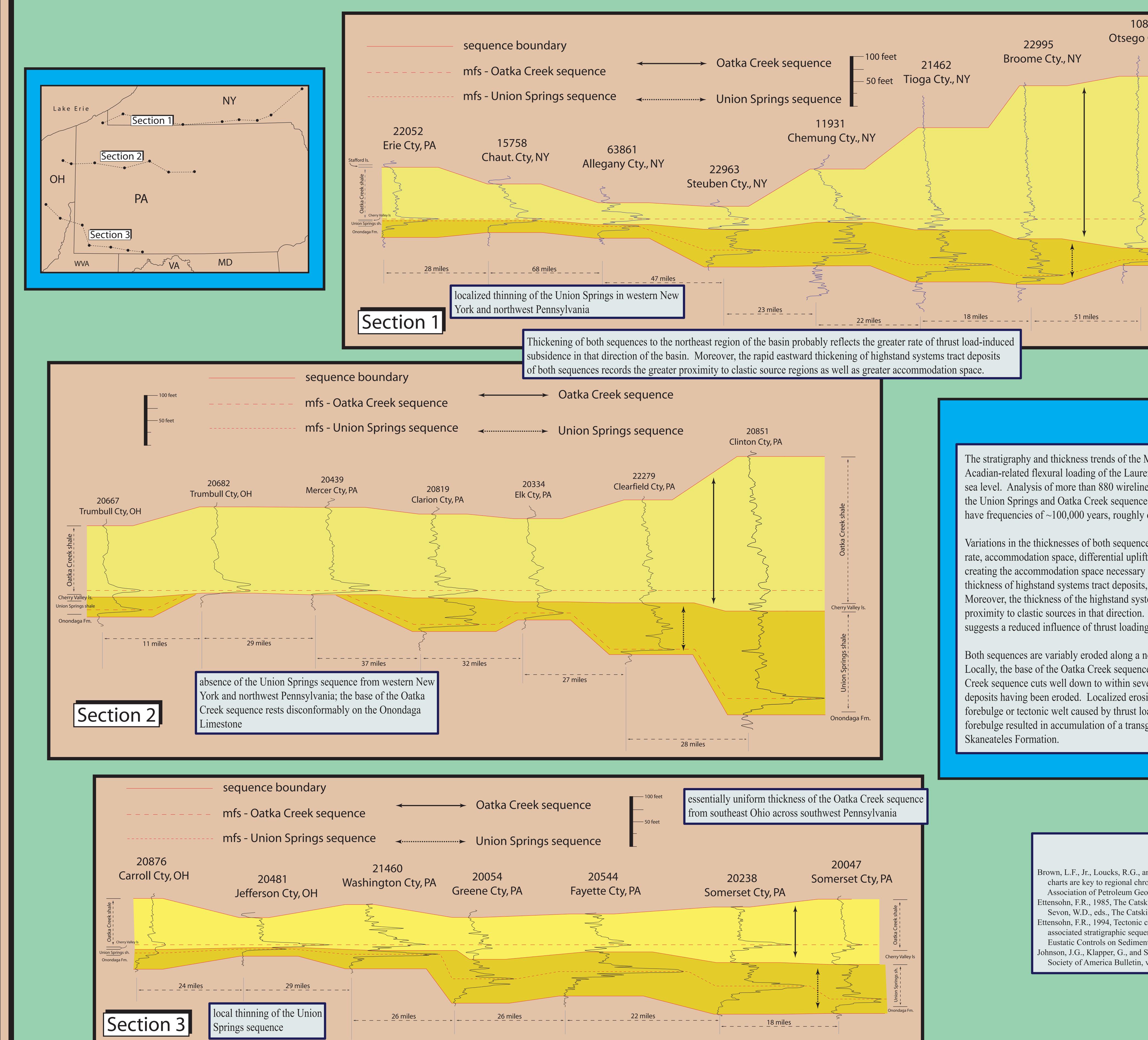






Parasequence (fourth order depositional sequences) stacking arrangement in the Union Springs and Oatka Creek shale members of the Marcellus Shale. The two Marcellus depositional sequences span ~1.5 MY (blue arrows denote the inferred fourth order cycles; arrows pointing to the right imply a landward shift of environments; arrows pointing to the left imply an offshore shift of

The stacking arrangement of parasequence sets reflects high frequency eustatic oscillations superimposed on the two third order cycles. The parasequences appear to have frequencies on the order of ~100,000 years, well within the Milankovitch band for Earth orbital eccentricity.



Conclusions

upper boundary of the Oatka Creek sequence cuts well down

into the Union Springs sequence in western New York

Otsego Cty., NY

The stratigraphy and thickness trends of the Middle Devonian Marcellus shale of the Appalachian Basin reflects the interplay of Acadian-related flexural loading of the Laurentian craton in response to oblique collision and high frequency fluctuations of relative sea level. Analysis of more than 880 wireline logs indicates that the Marcellus comprises two third order depositional sequences, the Union Springs and Oatka Creek sequences, in ascending order. Each sequence includes fourth order sequences that appear to have frequencies of ~100,000 years, roughly coincident with the Milankovitch band for Earth orbital eccentricity.

Variations in the thicknesses of both sequences across the core region of the basin reflect a complex relationship of sedimentation rate, accommodation space, differential uplift, eustacy and proximity to clastic sources. Thrust loading played a first order role in creating the accommodation space necessary for the accumulation of both sequences. Accommodation space as reflected in the thickness of highstand systems tract deposits, was greatest in the northeast region of the basin, proximal to the Acadian thrust load. Moreover, the thickness of the highstand systems tracts of both sequences increases markedly to the northeast reflecting greater proximity to clastic sources in that direction. The essentially uniform thickness of both sequences in southwestern Pennsylvania suggests a reduced influence of thrust loading in this region of the basin (i.e., lesser accommodation space).

Both sequences are variably eroded along a northeast-southwest-trending axis in western New York and northwestern Pennsylvania. Locally, the base of the Oatka Creek sequence rests disconformably on the Onondaga Limestone. Similarly, the top of the Oatka Creek sequence cuts well down to within several meters of the marine flooding surface, the bulk of the highstand systems tract deposits having been eroded. Localized erosion of the Marcellus was probably a consequence of the development of a small forebulge or tectonic welt caused by thrust loading in the hinterland. A subsequent rise in relative sea level and/or collapse of the forebulge resulted in accumulation of a transgressive systems tract that includes the Levanna black shale at the bottom of the Skaneateles Formation.

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- Brown, L.F., Jr., Loucks, R.G., and Trevino, R.H., 2005, Site-specific sequence-stratigraphic section benchmark charts are key to regional chronostratigraphic systems tract analysis in growth-faulted basins: American Association of Petroleum Geologists Bulletin, v. 89, p. 715-724.
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