



Carbonate and Siliciclastic Sequence Stratigraphy - Examples from the Late Jurassic Abenaki Limestone and West Venture Deltaic Beds, Offshore Nova Scotia, Canada

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Summary

Relative to their occurrence in thick siliciclastic sections, thin carbonates show utility as sensitive indicators of the surrounding sand and shale sedimentation. When composed of *in situ* framebuilders (microbial and skeletal) as demonstrated by inter-growth position, bioerosion, associated submarine cements and marine geopetals, the carbonates are particularly helpful for environmental inferences. Within the Sable Island paleodelta, cores in Penobscot L-30 and West Venture C-62 show both dark colors and limited biotic diversity with microbial textures. The C-62 cores are particularly interesting because they provide an independent check on the shelf-margin delta model and sequence stratigraphic scenario presented by Cummings and Arnott for the Venture gas field. In less than 7 metres, facies and fauna in limestone change upward from a biotically depauperate marl to a microbial mud mound which is succeeded by an argillaceous sponge-microsolenid coral reef mound with some stromatoporoids and possible red algae. The sequence is interpreted to reflect a forced regression and falling sea level. This closely supports the published deltaic sequence stratigraphy as long as it is appreciated that the "condensed limestone facies" is actually a distal composite, recording changes in sea level, nutrient supply, and ultimately sediment type that replaces the carbonate as the delta progrades. The maximum flooding surface (MFS) occurs during the microbial mound stage, below an abrupt lithologic change across a pyritized hardground which is overlain by laminated black shale. This placement of the MFS reflects problematic differences in sequence stratigraphic concepts of carbonates versus siliciclastics. Relative to understanding the Abenaki platform, the C-62 core provides insights into relationships seen only in cuttings and sidewall cores in Queensland M-88 which drilled the slope and basin facies immediately in front of the Deep Panuke (Abenaki reservoir) gas field. M-88 and C-62 may be potential links for correlating and dating the massive (Abenaki) carbonates and the deltaic siliciclastics. (This is a much abbreviated version of Eliuk and Wach 2008 of 28 pages with 19 figures.)

Introduction

The Upper Jurassic continental shelf off Nova Scotia has contemporaneous siliciclastic-dominated and carbonate-dominated sedimentation (Fig. 1). The former shows a progradational ramp style that continues on into the middle Cretaceous in the Sable Island area whereas the latter is mainly aggradational southwest of the Sable Island with various types of platform margin reefs developed (Eliuk 1978). Shelf margin deltas have been interpreted for several of the Sable Sub-basin gas fields (Cummings and Arnott 2005). Thus the paleo-

shelf edge is of economic interest for both sandstone and carbonate reservoirs with the discovery and development of Deep Panuke (Weissenberger 2006 et al., EnCana 2006). Limestone in the mixed-carbonate-siliciclastic settings has not been porous but may give insights into the associated sandstone reservoirs or potential reservoirs and their depositional setting and sequence history. Only two wells have cored limestone in these mixed lithologies; but provide a spectrum from very thin limestone completely within the delta (West Venture C-62 #9 Limestone) to deep and shallow carbonate ramp settings just in front of the carbonate platform (both cored in Penobscot L-30) to interbedded prodeltaic-slope shales in front of and infilling topography on the thick carbonate platform slope with the mixed slope carbonates and shales drilled but only side-wall cored in Queensland M-88 immediately in front of the Deep Panuke platform margin discovery.

Setting – paleogeographic and stratigraphic with limestone facies from cuttings

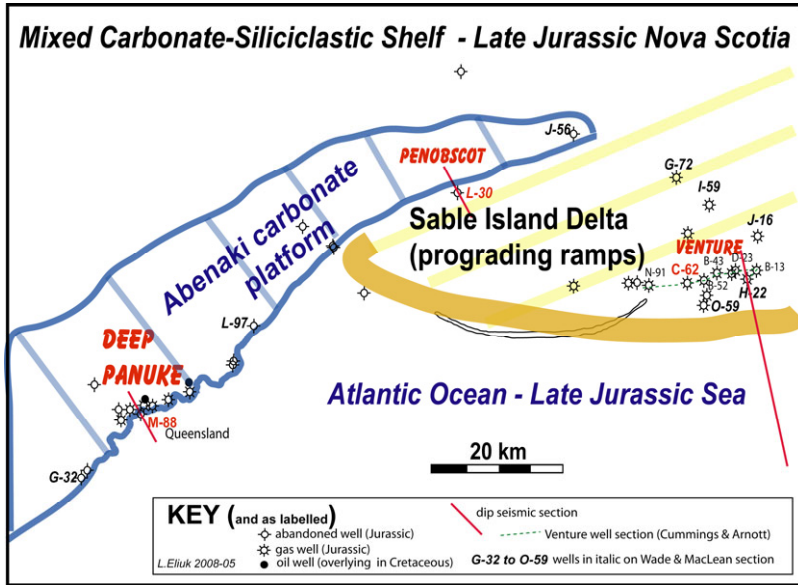


Figure 1. Regional setting of Late Jurassic carbonate platform and Sable Island delta with intervening prograding ramp showing three key locations, wells and seismic lines approximately – Venture area with West Venture C-62, Penobscot L-30 and Deep Panuke with Queensland M-88 on adjacent reef slope. Seismic in L-30 and M-88 show clinofolds and support a deeper water setting for microbialites recovered in whole and sidewall cores that then can be used for supporting a deeper-water setting for microbialites seen in the #9 limestone core in C-62. Seismic can be seen in Eliuk and Wach 2008 and Kidston et al. 2005

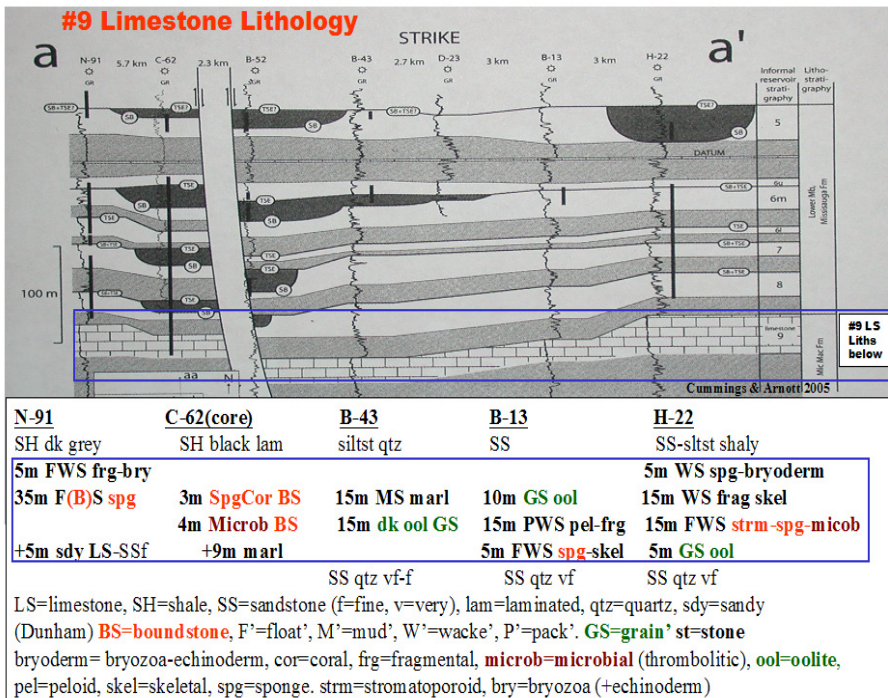


Figure 2. Venture area #9 Limestone lithologies – based on 5m cuttings samples for all but C-62 well. Colors indicate either red for reefal (10% or greater framebuilders - lithistid/siliceous sponges, stromatoporoids, corals mainly microsolenid) or green for oolite grain/packstones. In Venture B-52 most of the #9 Limestone is faulted out except for 10 m of marl-argillaceous mudstone with minor black ooids. Section is from Cummings and Arnott 2005 showing their sequences and facies of ‘dark grey’= strongly tidally influenced estuarine incised valley fill, ‘light grey’= storm dominated delta front sandstone, ‘medium grey’= prodelta mudstone and ‘limestone symbols’= condensed shelf limestone

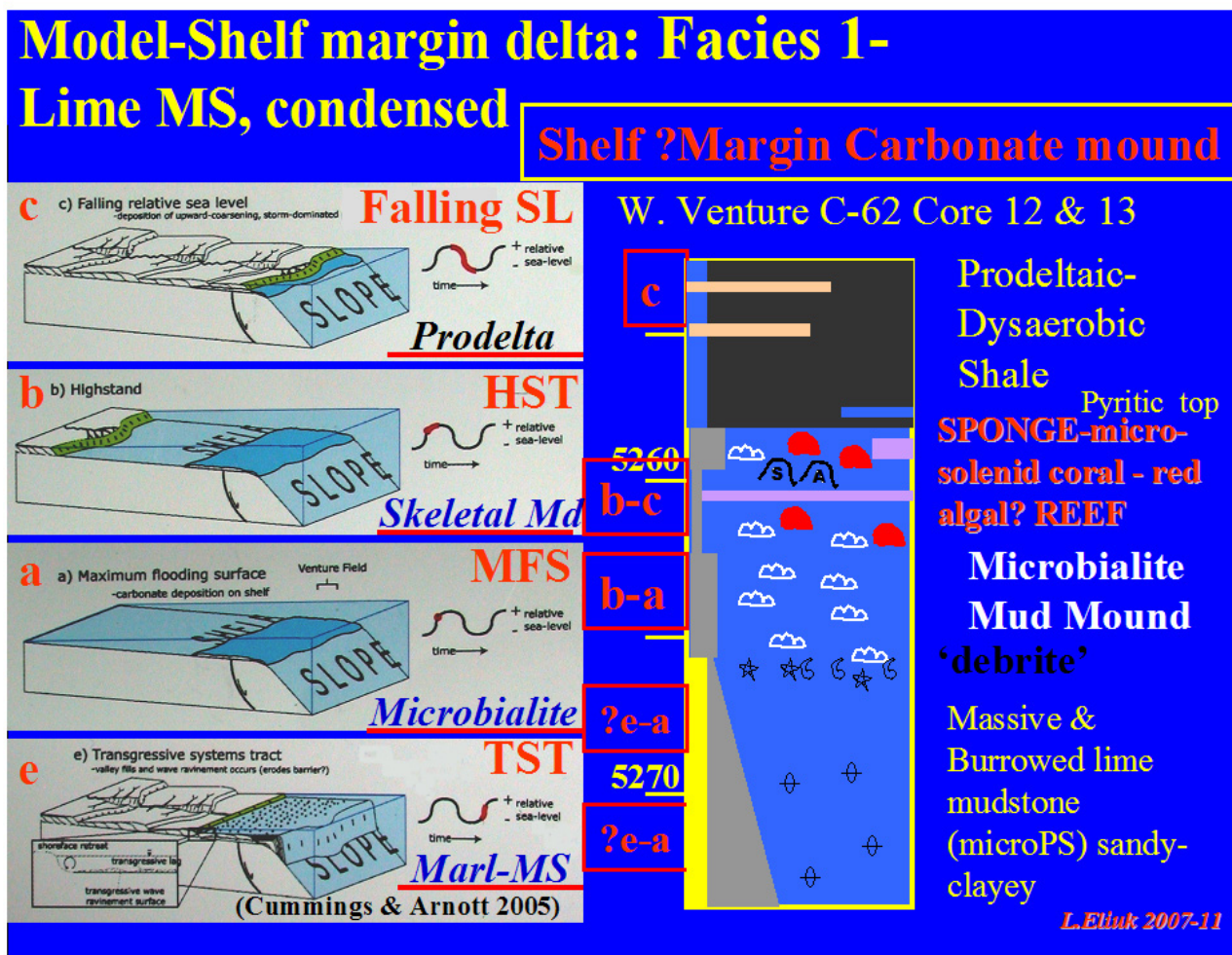


Figure 3. West Venture C-62 #9 Limestone core depo-lithofacies compared to depositional model of Cummings and Arnott (2005) – note the interpreted transgressive or deepening trend in the relatively thin limestone facies from highly bioturbated deeper-shelf calcareous shale/marl up to massive marl (micro-packstones) then microbial boundstone (“mud mound”) compatible with the model’s transgressive (TST), maximum flooding (MFS) and highstand (HST) systems tracts then the reversal to a regressive or shoaling trend of microbial-microsolenid coral-lithistid sponge-red algal? (solenopodid?) reef mound abruptly overlain by laminated prodeltaic or lower shoreface shales/mudstones with a pyritized hardground contact that is the most abrupt lithologic change, but not the deepest deposition. Given the thinness of the limestone making depositional elevation into photic and less nutrient-rich depths unlikely, this reversal is best explained by falling relative sea level that allowed skeletal framebuilder replacement of the pure microbialites in spite of the increasing clay content (see Eliuk and Wach 2008 Appendix for core gamma log and additional facies illustrations).

Conclusions

A thin limestone succession is used to give paleoecological support to falling sea level causing forced regression in a shelf-margin delta depositional sequence model of Cummings and Arnott (2005). Initially this support was based on the study of a single cored limestone that was then supplemented by limestone cuttings in nearby wells of the Venture area near Sable Island offshore Nova Scotia, Canada. If only the West Venture C-62 core is considered (Fig. 3) an uncomplicated argument can be made for a fall in relative sea level to explain change from deep-water marl and pure microbial boundstone to microbial-microsolenid coral-sponge boundstone in only a few metres of buildup. The limestone is indeed condensed but has many facies changes as relative sea level and clays-nutrient supply changes caused water clarity and photic changes; still deep but clear and light enough for

skeletal framebuilders and possible deep-water red algae (solenoporids). This microbial-skeletal reef mound is shallower than the maximum flooding zone represented by microbialite boundstone and massive marl that has sponge spicules and delicate articulated bivalves (possibly nektonic). The increase in clays and dysoxia-anoxia with the approach of the prograding delta eventually kills off the carbonate sediment producers and a dysaerobic pyritized submarine hardground is covered by laminated prodelta shale. Thus the changes on the outer shelf in the thin (about 15m) limestone-marl, that shows no evidence for subaerial exposure or even very shallow deposition, mirror and record the relative sea level changes that control the siliciclastic sedimentation and progradation over about 70m (lower Lower Missisauqua Formation basal sequence of #8 Sandstone and #9 Limestone) occurring on the inner shelf nearer to shore and to the river mouth as depicted in Cummings and Arnott's (2005) shelf-margin delta depositional sequence model. When more of the #9 Limestone wells (Figs. 2) are included, C-62 and B-52 (perhaps H-22) are in relatively deeper facies. And these wells (at least C-62 and B-52) have many overlying channels and thus continued to be a bathymetrically deep or low. The oolite-bearing, more shelfward limestone in wells (B-13 and B-43), suggests an original paleohigh and not surprisingly overlying channels are absent. This could be evidence for early seafloor topography perhaps related to local tectonics that controlled the later positions of channels.

These conclusions follow from a general acceptance of Cummings and Arnott's (2005) depositional model and the assumption that the section from the highly burrowed marls below and up through the limestone and the clay mudstone prodeltaic beds, to the overlying coarsening up sandstones are all a single depositional sequence of a prograding delta during a forced regression. If an alternative channel and delta-lobe switching and/or an independent sub-sequence of carbonate-prone sedimentation is recorded here, then there would be no continuous sequence connection between the overlying siliciclastic sedimentation and the different events recorded in the C-62 core or mapped for the #9 Limestone. The top of the limestone might be the sequence break at a submarine hardground surface during a local switch from maximum regression (the microbial-skeletal reef mound) to transgression (the basal prodeltaic shales) complicated by changes in oxidation levels. The thin limestone would not be just a condensed maximum flooding zone. It might be a complete condensed sequence with the maximum transgression (MFS) in the marl-microbialite and the maximum regression in the top of the skeletal reef mound only 5-8 m higher.

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