geoconvention
Virtual Event
September 21-23
2020
CSPG • CSEG • CWLS • GAC • MAC • IAH

Estimation of system tracts variation in Turonian Ferron Notom deltaic complex in south-central Utah, U.S.A. by the approach of parasequence thickness to sandstone fraction ratio

Tuoyu Wu, Janok P. Bhattacharya
School of Geography and Earth Sciences, Mcmaster University

Summary

The parasequence thickness to sandstone fraction ratio (TSF) has been recently proposed as a simple tool to identify stratal stacking patterns and associated system tracts of conformable coastal margin siliciclastic sequences (Ainsworth et al., 2011, 2018; Vakarelov and Ainsworth, 2013). TSF analysis can be applied to outcrops, cores, well logs and seismic profiles. The average TSF ratio for each coastal margin parasequence along both dip-oblique and strike-oblique sections of the Ferron Notom Delta has been utilized to identify TSF trends. These compare favorably with previously identified sequences and systems tracts, and reveals close correspondence with previous architectural-facies studies (Zhu et al., 2012), suggesting that this is a viable quantitative technique.

Introduction

The parasequence thickness to sandstone fraction ratio (TSF) is a newly-developed sedimentological method to interpret clastic coastal systems based on integrated analyses of parameters, such as accommodation development, sediment supply, shoreline trajectory, and shelf width (Ainsworth et al., 2011, 2018; Vakarelov and Ainsworth, 2013). TSF analyses mainly focuses on analysis of allogenically-forced fourth-fifth order shallow marine and deltaic parasequences with regressive-transgressive shoreline transits of 10^4-10^5 year duration (Ainsworth et al., 2018). The sequence stratigraphy of the Ferron Notom deltaic complex is dominated by Milankovitch-scale sequences and systems tracts developed during stepped forced regression on the western margin of the Cretaceous Western Interior Seaway (Zhu et al., 2012). The well-established dip-oblique and strike-oblique sections by Zhu et al. (2012) provide the opportunity to conduct a TSF analysis on the Ferron Notom deltaic complex to test whether it matches the previously defined high-frequency sequences and component systems tracts.

Principles and methods

Parasequence thickness (T) is used to simulate the change of accommodation; while sandstone fraction (SF) can be treated as a proxy for sediment supply. The vertical TSF trend is used to classify stacking patterns and associated system tracts. Upward increase of TSF indicates retrogradational (R) or progradational-aggradational (PA) accommodation successions; while upward decrease of TSF corresponds to aggradational-progradational-degradational (APD) accommodation successions (Neal and Abreu, 2009). R, PA, and APD accommodation successions correspond to transgressive (TST), lowstand (LST), and highstand to falling-stage (HST-FSST) system tracts, respectively. Usually, FSST shows relatively smaller T/SF values and a more rapidly decreasing TSF trend than the HST along dip-oblique sections (Ainsworth et al., 2018). TST can be distinguished from LST by its relatively smaller T/SF value (< 10) along dip-oblique transect, and its relative position with respect to HST (Figure. 1).

The workflow of the TSF analyses involve four major steps. Firstly, measure parasequence thickness (T) and sandstone thickness of each parasequence (Ts) based on 49 actual measured sections and 34 hypothesized sections (Figure 1). If a section only penetrates the mudstone portion of a parasequence, the grain size of mudstone can be used as a proxy of sand percentage (SF). The 0% of the SF is marked at the mean clay scale, and the 100% of the SF is emplaced at the lowest limit of very fine sand scale. The second step is to calculate T^2/Ts, namely the T/SF value, for each parasequence of the Ferron Notom deltaic complex along both strike and dip. Thirdly, interpret accommodation successions and corresponding system tracts based on the mean T/SF value for each parasequence, and TSF trend within each parasequence set. Fourthly, determine the key surfaces between the interpreted system tracts. Lastly, compare the TSF analyses of the Ferron Notom deltaic complex with the previous sequence stratigraphic study of Zhu et al. (2012).

Results and discussion

Zhu et al. (2012) defined 5 depositional sequences, 18 parasequence sets, and 43 parasequences in the Ferron Notom deltaic complex. In this study, only the shallow marine and delta parasequences (parasequence 4-43) along the dip-oblique (Figure. 1) and strike-oblique (Figure. 2) views are used for TSF analyses. According to Table 1, the TSF analyses show similar stacking patterns and corresponding system tracts as Zhu's et al. (2012) but with several discrepancies. For example, parasequence set 12 was interpreted as an HST showing an AP accommodation succession, but the TSF analysis shows two TSF decreasing trends within the parasequence set. The lower slow declining trend from 12d to 12c is regarded as HST; the upper quick falling trend from 12b to 12a is herein considered to be FSST (Figure. 1). However, this system tract division disregards the overall decreasing trend of parasequence set 12. Although parasequence 12b is indeed muddier, as shown in the dip-oblique view (Figure. 1), the original sandstone deposits may be underestimated. This is mainly because parasequence 12b is top-truncated by incised valleys, which caused significant erosion of its sandy portion (Figure. 1). Another example concerns parasequence set 11, which was solely attributed to FSST based on stratal termination of offlap and downlap demonstrated by Zhu et al. (2012). Comparatively, the TSF analyses classify parasequence 11d and 11e with relatively higher TSF ratio as HST; but attribute parasequence 11c, 11b and 11a with small TSF ratios to be FSST. However, detailed observation of the shoreline trajectory shows distinct sea-level drop from parasequence 11e to 11d. From parasequence 11d to 11a, shoreline gradually prograded seawards without major sea-level fluctuation. This suggests a depositional stage with medium sea-level during transition from HST to LST, which can be named as a mid-stand system tract. The third major difference lies in the interpretation of parasequence 4 and 5. The TSF analyses would assign parasequence 4 to an LST related PA succession based on the ascending TSF trend with respect to the underlying parasequence 5. The high TSF ratio of parasequence 4 may reflect a significant mudstone proportion in the bayhead delta, bay-lagoon fills and offshore transition facies. An alternate interpretation by Zhu et al. (2012) categorized parasequence 4 as part of an HST.

TSF analyses of both the dip-oblique and strike-oblique transects are quite similar, but the dip-oblique transect provides far more information about successions and associated system tracts than the strike-oblique counterpart (Figure. 1 and 2). This reflects the fact that the oblique-depositional-strike section does not contain many of the parasequences, and is therefore incomplete. Even without consideration of special cases in the sequence stratigraphic cross sections, the stacking patterns and associated system tracts deduced from TSF analyses show 70% correlation with Zhu's et al (2012) architectural-facies studies (Table 1). If we take the factors such as valley erosion and shoreline trajectory into consideration, the whole parasequence set 12 can be categorized to HST, and the parasequence 11e, 11d can be attributed to FSST. This amendment will improve the accuracy of the TSF analyses, and render more than 90% similarity to Zhu's et al. (2012) work. Above all, the TSF analyses of the Ferron Notom deltaic complex indicate TSF method is an easy-to-use but effective tool in predicting or double-checking successions and associated system tracts in sequence stratigraphic correlation; however, valid TSF interpretation is always built upon detailed architectural-facies studies.

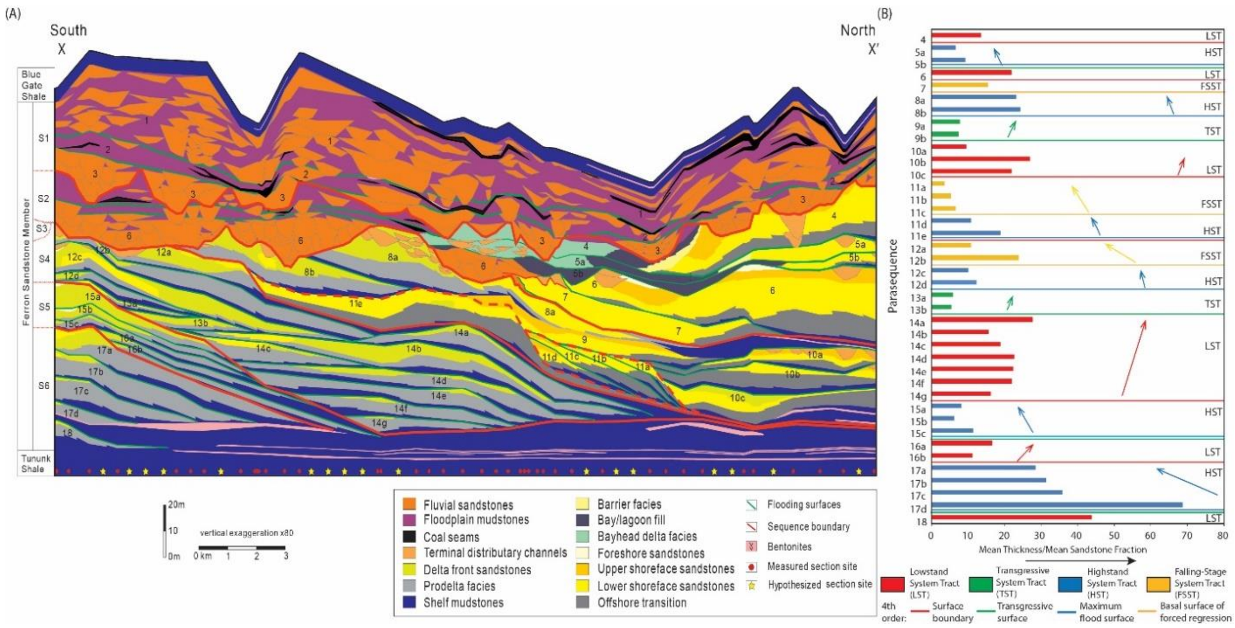

Figure 1. (A) Oblique-depositional-dip cross section (X-X') of the Ferron Notom deltaic complex (Zhu et al., 2012). (B) The TSF analyses for each of the 40 parasequences. Red arrows are for progradation-aggradation successions; green arrows are for retrogradation successions; blue arrows are for aggradation-progradation successions; yellow arrows are for degradation successions.

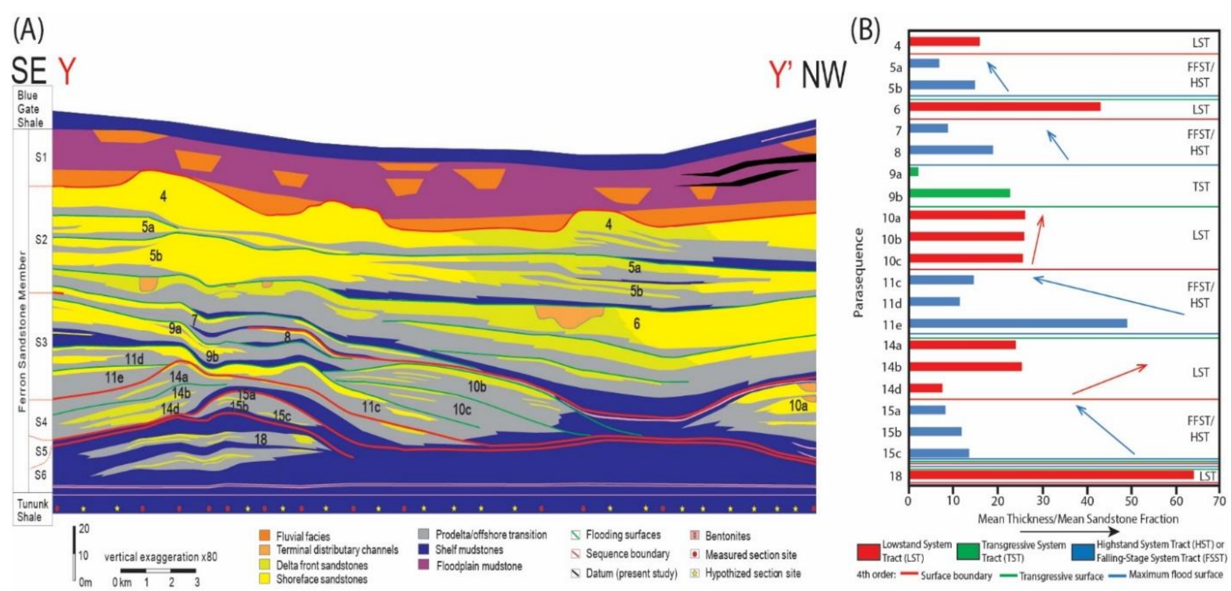

Figure 2. (A) Oblique-depositional-strike cross section (Y-Y') of the Ferron Notom deltaic complex (Zhu et al., 2012). (B) The TSF analyses for the observed 11 parasequences on the cross section. Red arrows are for progradation-aggradation successions; green arrows are for retrogradation successions; blue arrows are for aggradation-progradation successions; yellow arrows are for degradation successions.

Sequence	Parasequence set	Parasequence	Stacking pattern (the TSF analyses)	System tract (the TSF analyses)	Shoreline trajectory (the TSF analyses)	Stacking pattern (Zhu et al., 2012)	System tract (Zhu et al., 2012)	Shoreline trajectory (Zhu et al., 2012)
1	1	1	N/A	N/A	N/A	A*	HST	Ascending regressive
	2	2	N/A	N/A	N/A	R*	TST	Ascending transgressive
	3	3	N/A	N/A	N/A	A*	LST	Ascending regressive
2	4	4	PA	LST	Ascending regressive	P	HST	Ascending regressive
	5	5a, 5b	AP	HST	Ascending regressive	A		Ascending regressive
	6	6	PA	LST	Ascending regressive	PA	LST	Ascending regressive
	7	7	D	FSST	Descending regressive	D	FSST	Descending regressive
3	8	8a, 8b	AP	HST	Ascending regressive	AP	HST	Ascending regressive
	9	9a, 9b	R	TST	Ascending transgressive	R	TST	Ascending transgressive
	10	10a, 10b, 10c	PA	LST	Ascending regressive	PA	LST	Ascending regressive
	11	11a, 11b, 11c	D	FSST	Descending regressive	D	FSST	Descending regressive
		11d, 11e	AP	HST	Ascending regressive			
4	12	12a, 12b	PA	FSST	Descending regressive	AP	HST	Ascending regressive
		12c, 12d	AP	HST	Ascending regressive			
	13	13a, 13b	R	TST	Ascending transgressive	R	TST	Ascending transgressive
	14	14a, 14b, 14c, 14d, 14e, 14f, 14g	PA	LST	Ascending regressive	PA	LST	Ascending regressive
5	15	15a, 15b, 15c	AP	HST	Ascending regressive	AP	HST	Ascending regressive
	16	16a, 16b	PA	LST	Ascending regressive	A	LST	Ascending regressive
6	17	17a, 17b, 17c, 17d	AP	HST	Ascending regressive	AP	HST	Ascending regressive
	18	18	PA	LST	Ascending regressive	PA	LST	Ascending regressive

Table 1. Summary of stacking patterns, system tracts, and shoreline trajectories of the Ferron Notom deltaic complex by Zhu et al. (2012).

Acknowledgements

Funding for this project was generously supplied by NSERC Discovery Grants to Dr. Bhattacharya, by sponsors of the McMaster University Quantitative Sedimentology Laboratories (QSL) which have included BP, Inpex, and Ecopetrol, and by the Susan Cunningham Research Chair in Geology.

References

Ainsworth, R. B., J. B. McArthur, S. C. Lang, and A. J. Vonk, 2018 Quantitative sequence stratigraphy: AAPG Bulletin, v. 102, no. 10, pp. 1913–1939, doi: 10.1306/02201817271.

Ainsworth, R. B., B. K. Vakarelov, and R. A. Nanson, 2011, Dynamic spatial and temporal prediction of changes in depositional processes on clastic shorelines: Towards improved subsurface uncertainty reduction and management: AAPG Bulletin, v. 95, no. 2, p. 267–297, doi: 10.1306/06301010036.

Neal, J. E., and V. Abreu, 2009, Sequence stratigraphy hierarchy and the accommodation succession method: Geology, v. 37, no. 9, p. 779–782, doi:10.1130/G25722A.1.

Vakarelov, B. K., and R. B. Ainsworth, 2013, A hierarchical approach to architectural classification in marginal marine systems – Bridging the gap between sedimentology and sequence stratigraphy: AAPG Bulletin, v. 97, no. 7, p. 1121–1161, doi: 10.1306/11011212024.

Zhu, Y., J. P. Bhattacharya, W. Li, T. J. Lapen, B. R. Jicha, and B. S. Singer, 2012, Milankovitch-scale sequence stratigraphy and stepped forced regressions of the Turonian Ferron Notom deltaic complex, south-central Utah, U.S.A.: Journal of Sedimentary Research, v. 82, no. 9, p. 723–746, doi: 10.2110/jsr.2012.63.