Redistribution of Organomineralic Aggregate Grains in the Upper Cretaceous Second White Specks Formation, Western Canada Foreland Basin

Burns A Cheadle

Department of Earth Sciences, Western University, London, Ontario

Summary

Recent research into the depositional processes governing mudstone microfabric reveals that organic matter in the Upper Cretaceous Colorado Group have have been redistributed by vigorous bottom currents. This interpretation offers a potential method for prediction of the vertical and lateral distribution of enhanced kerogen content within a high-frequency stratigraphic framework.

Introduction

The matrix storage and flow capacity of self-sourcing carbonaceous mudstone (shale) reservoirs depends on depositional, diagenetic and compactional modification of intergranular volume, as well as the creation of microporosity associated with the conversion of disseminated organic matter to petroleum and natural gas. The prediction of porosity, permeability and hydrocarbon charge in a shale prospect, therefore, should be informed by a fundamental understanding of the processes involved in constructing the mudstone microfabric. Despite the abundance of mudstone in the sedimentary record, studies of the sedimentology and petrology of these rocks have only recently begun to reveal aspects of their formation that have a direct bearing on risk analysis of their commercial potential.

Theory and/or Method

The classical interpretation of mudstone depositional processes (vertical settling from suspension in a relatively still water column) has undergone reappraisal during the past decade. Recent experimental data (Schieber et al. 2007; Nishida et al. 2013) and observations from modern and ancient sediments (Macquaker et al. 2010a; Plint et al. 2012) provide compelling evidence that mud is commonly transported as bedload of various types of aggregate grains by currents with velocities sufficient to transport fine-grained sand. The sedimentary structures in mud aggregate deposits preserve a record of advective transport, erosion, and redistribution across low-gradient ramps or shelves for distances of several hundreds of kilometres offshore (Plint 2013).

Scanning electron (SEM) examination of Colorado Group mudstones revealed three distinct classes of mud aggregate grains distributed across the wave-dominated, low-gradient ramp that spanned the Western Canada Foreland Basin (WCFB) (Plint et al. 2012; Jiang and Cheadle 2013): (a) intraclastic aggregates produced by erosion of (semi-)consolidated mud,

(b) faecal pellets, and (c) organomineralic aggregates (OMA) analogous to modern marine snow / phytodetritus (Macquaker et al. 2010b). Both the intraclastic aggregates and OMA contain smaller "face-face" aggregates (O'Brien 1987) which are, in turn, aggregations of clay "domains" (Bennett et al. 1981). Crucially, both intraclastic aggregates and OMA are intimately mixed within event deposits in Colorado Group mudstones (Fig. 1), suggesting that both particle types were redistributed simultaneously by bottom currents.

Example

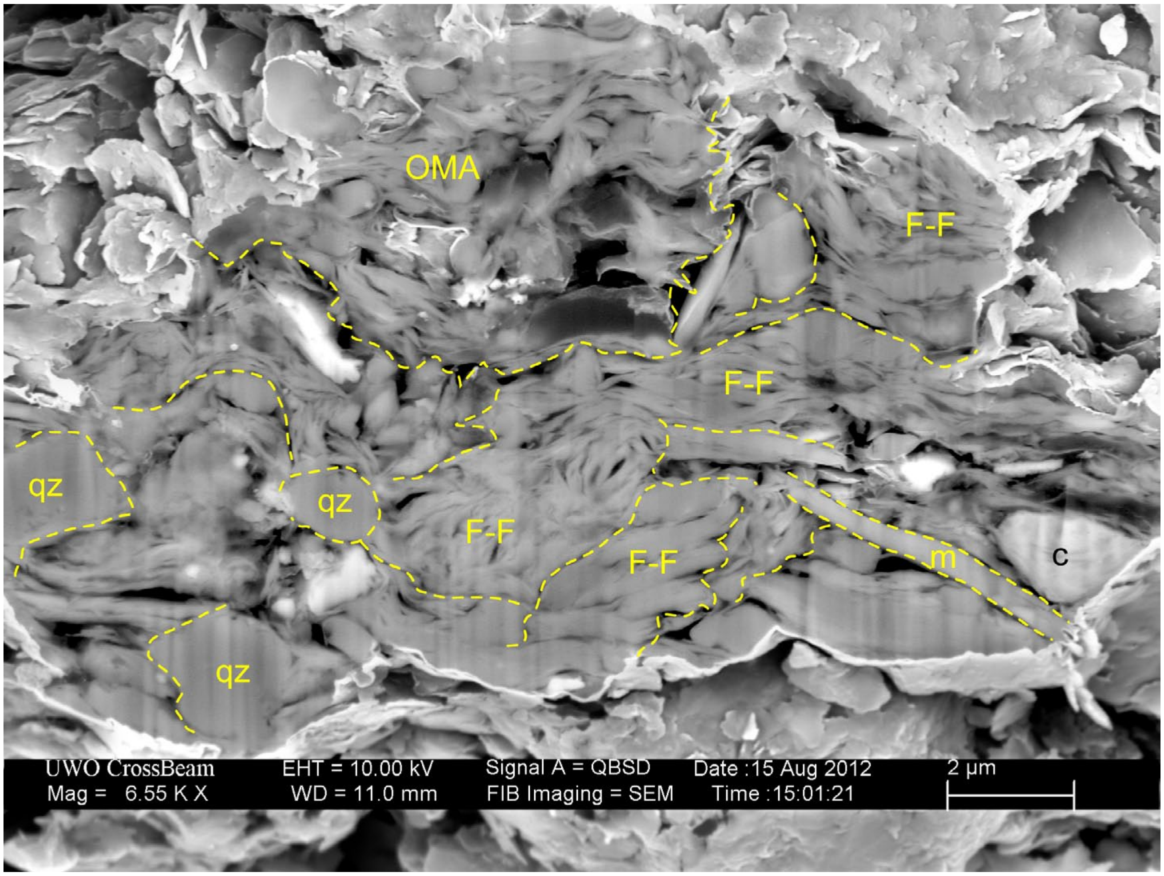

Figure 1. Backscatter scanning electron photomicrograph of a focused ion beam (FIB) milled surface, Second White Specks Formation, Saskatchewan (well location withheld for proprietary research). The yellow dashed lines are interpreted outlines of the aggregate particles that constitute the fundamental "clasts" of a typical Colorado Group mudstone. An organomineralic aggregate (OMA, upper middle region of the image) is packed adjacent to several face-face (F-F) aggregates. The F-F aggregates, along with the isolated very fine quartz (qz) and carbonate (c) silt grains, may be constituent particles of a larger intraclastic aggregate grain that is larger than the field of view. The image is visual evidence of the mixture of OMA with other clay aggregate grains within a single depositional event, indicative of a dynamic process to redistribute organic matter through advective transport across the low-relief ramp setting.

Conclusions

Whereas OMA are generally considered to be formed by clay-OM adhesion during episodic phytoplankton blooms, and subsequently deposited by rapid vertical settling through the water column, the textural evidence suggests that the particles are sufficiently cohesive to permit resuspension and transport by bottom currents that also carry intraclastic aggregates as bedload. Alternatively, the OMA may become incorporated into the consolidated mud that is subsequently eroded to form intraclastic aggregate grains. In either case, this is significant because it represents a process for redistribution of preserved organic matter beyond the limited location and period of a single phytoplankton bloom episode.

Plint et al. (2012) have postulated that the reworking of cohesive mud occurred within the "mud accommodation envelope" during transgressive and highstand times in the WCFB, whereas falling-stage and lowstand times were generally characterized by wave erosion, bypass and exhumation. This model provides a framework for predicting the stratigraphic context of redistribution of organic matter in the form of aggregate grains, and represents a potential method for shale prospect risking.

Acknowledgements

The author thanks Husky Energy, Devon Canada Corporation and Tuzo Energy for research funding and continued sponsorship of the Second White Specks Liquids-Rich Research Consortium at Western University. I also thank Melinda Yurkowski and the staff of the Subsurface Geological Laboratory in Regina for access to Saskatchewan core samples. Software and well data were donated by geoLOGIC systems ltd., IHS Energy (Canada) Ltd., Divestco Inc. and Schlumberger Limited. Many thanks to Dr. Guy Plint who is always willing to provide insight and guidance.

References

Bennett, R.H., Bryant, W.R. and Keller, G.H. 1981. Clay fabric of selected submarine sediments: fundamental properties and models. Journal of Sedimentary Petrology, **51**: 217–232.

Jiang, P. and Cheadle, B. 2013. Depositional and Burial Domain Influences on Microporosity Modalities in Carbonaceous Mudstones of the Upper Cretaceous Colorado Group, Western Canada Foreland Basin (poster presentation). AAPG Annual Convention and Exhibition: May 19 – 22 2013, Pittsburgh, PA. Available from: http://www.searchanddiscovery.com/documents/2013/50802jiang/ndx_jiang.pdf [cited 10 January 2014]

Macquaker, J.H.S., Bentley, S.J., and Bohacs, K.M. 2010a. Wave-enhanced sediment gravity flows and mud dispersal across continental shelves: Reappraising sediment transport processes operating in ancient mudstone successions. Geology, **38**: 947–950.

Macquaker, J.H.S., Keller, M.A., and Davies, S.J. 2010b. Algal blooms and "marine snow": mechanisms that enhance preservation of organic carbon in ancient fine-grained sediments. Journal of Sedimentary Research, **80**: 934–942.

Nishida, N., Ito, M., Inoue, A. and Takizawa, S. 2013. Clay fabric of fluid mud deposits from laboratory and field observations: potential application to the stratigraphic record. Marine Geology, **337**: 1–8.

O'Brien, N.R. 1987. The effects of bioturbation on the fabric of shale. Journal of Sedimentary Petrology, **57**: 449-455.

Plint, A.G. 2013. Mud dispersal across a Cretaceous prodelta: Storm-generated,wave-enhanced sediment gravity flows inferred from mudstone microtexture and microfacies. Sedimentology, **doi**: 10.1111/sed.12068

Plint, A.G., Macquaker, J.H.S. and Varban, B.L. 2012. Bedload transport of mud across a wide, storm-influenced ramp: Cenomanian-Turonian Kaskapau Formation, Western Canada Foreland Basin. Journal of Sedimentary Research, **82**: 801–822.

Schieber, J., Southard, J.B., and Thaisen, K.G.. 2007. Accretion of mudstone beds from migrating floccule ripples. Science, **318**: 1760–1763.