JGS
Journal of the Geological Society

Published online August 18, 2016

doi:10.1144/jgs2016-078 | Vol. 173 | 2016 | pp. 801–802

Introduction to the future of sequence stratigraphy: evolution or revolution?

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Received 1 July 2016; **accepted** 1 July 2016

Sequence stratigraphy was first developed as concepts and methods from the late 19th to mid 20th century by geologists such as Barrell and Sloss. It is now at the forefront of how sedimentary geologists observe, record, model and predict strata. The Geological Society William Smith meeting in Burlington House in September 2014 considered the current state and future developments in sequence stratigraphy, and focused particularly on how the subject should progress, either by evolution or by revolution. We feel that this is a relevant question because of continuing debate, and in some cases controversy, about what sequence stratigraphy is, how we do it and what it can be used for. For example, one of the major hindrances to progress has been the interweaving of description and interpretation, mixing method with model. This has been pointed out and discussed by various researchers (Helland-Hansen & Gjelberg 1994; Burgess & Prince in press). This thematic set of papers presents a sample of the state-of-the-art in sequence stratigraphy, representing how the method and model is now being debated and developed, from a plea to retain the earliest version of the concept to the inclusion of more radical ideas stimulated from experimental stratigraphy.

Emphasizing the importance of a clear distinction between method and model, and building on their important earlier paper (Neal & Abreu 2009), Neal *et al.* (2016) describe the latest sequence stratigraphic thinking of the Exxon group. They describe how the accommodation succession method is a refinement of previous sequence stratigraphic methods and emphasize the importance of following a common method to make observations. A key focus of the method is to keep observations of sedimentary facies, stratal stacking and terminations as objective as possible and distinct from interpretations of driving mechanisms. This is clearly an important and constructive point, but we would argue that this may not be enough; systems tract terminology should be free from any use of terms related to driving mechanism because some, arguably many, systems tract geometries are non-unique, with similar geometries occurring in response to different forcing mechanisms (Burgess & Prince 2015). Thus we encourage some standardization of method but not of interpretation. The paper by Neal *et al.*, therefore, is a particularly important contribution that should prove a useful guide to careful application of the sequence stratigraphic method.

Hampson (2016) uses Upper Cretaceous strata in the Book Cliffs to demonstrate how an outcrop interpretation can define a stratigraphic solution set, *sensu* Heller *et al.* (1993). This incorporates both allogenic and autogenic responses within a sediment routing conceptual framework, acknowledges non-uniqueness and, importantly, avoids limiting interpretation to one dominant control. The autogenic processes they consider include delta lobe switching, channel avulsion, auto-retreat and variations in sediment supply that control stacking patterns. This is an important piece of work, not least because sequence stratigraphic interpretations of outcrop that fully consider sediment routing and the possible contribution of autogenic processes are still relatively rare (Burgess 2016), so demonstrating how this can be done well is useful.

Muto *et al.* (2016) discuss issues related to the operation of autogenic processes that are more complex than the processes explicitly included in most sequence stratigraphic conceptual models. After beating this drum since 1992 (Muto & Steel 1992), they emphasize how it is the experimental side of stratigraphy that is now challenging existing conceptual models, and breaking new ground in understanding how depositional systems work. New observations and understanding from experiments are challenging even basic concepts such as accommodation by providing examples where original definitions do not work well. For example, the experimental case of a river feeding a prograding delta with stationary or rising relative sea-level when the limit to aggradation cannot be defined makes the concept of base-level and hence accommodation difficult to apply. From examples like this, Muto *et al.* make the case for careful inclusion of results from analogue and numerical modelling in sequence stratigraphic models and methods, with a particular focus on improving our understanding of how autogenic processes work, what they produce, how they interact with allogenic forcing, and their time-scale of operation.

In contrast to Muto *et al.* and Hampson *et al.*, and to some degree contrasting with Neal *et al*. too, Ridente (2016) argues for a return to the earliest view of sequence stratigraphy where accommodation variations, specifically glacioeustatic fluctuations, were the direct and dominant control on development of stratigraphic sequences. Ridente argues for this with an example of seismically imaged Quaternary strata from the Gulf of Mexico. He suggests that glacioeustatic oscillations shaped stratal geometries in a particular and characteristic manner demonstrably different from how changes in accommodation produce sequences during times lacking such high-amplitude, high-frequency relative sea-level oscillations. It is interesting to note that Ridente (2016) uses data from the same stratigraphic interval on the same continental margin as Neal *et al.* (2016), yet reaches what seem to be very different conclusions; perhaps proponents of a standardized sequence stratigraphic method and workflow have some work left to do.

The final paper in the set has a rather different focus. Turner *et al.* (2016) apply sequence stratigraphy to fine-grained strata in Oklahoma, using surfaces and facies shifts recognized through use of chemostratigraphy. They link particular chemostratigraphic signatures to accommodation control to define systems tracts and subdivide the fine-grained strata on this basis. The extent to which such subdivisions actually relate to accommodation perhaps requires independent evidence to demonstrate, but this work is a good example of the potential and the challenges in applying the sequence stratigraphic method to less frequently studied datasets.

Considering again the title of the William Smith meeting that led to these papers, is the future of sequence stratigraphy more likely to be evolution or revolution? These various papers perhaps give some indication of how this could go; if the view of Neal *et al.* (2016) is correct, evolution of the method has already made significant progress in providing a useful and predictive tool. Challenges arising in how to apply the method to new types of data (Turner *et al*. 2016), or how to adapt it for particular forcing mechanisms (Ridente 2016) do not preclude an evolutionary approach. Hampson (2016) arguably also supports this view, because inclusion of multiple interpretations and source-to-sink concepts (Martinsen *et al.* 2010) does not necessarily represent a revolutionary change in ideas about how depositional systems work or how they should be interpreted. However, inclusion of analogue and numerical experimental results (Muto *et al.* 2016) does have the potential to bring revolutionary change to sequence stratigraphy through new and possibly radical evidence about how depositional systems work. If the papers in this set are a representative sample, it will be evolution not revolution, but then again, perhaps all it would take for revolution is one radical experimental result.

Acknowledgements and Funding

The 2014 William Smith meeting was generously funded by BG Group, ENI, Neftex, SEPM and the Geological Society of London. We would also like to thank all the Geological Society staff who hosted and facilitated the meeting.

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