Unconformity bounded sequences are a natural consequence of mantle dynamics at rifted margins

Randell Stephenson*, School of Geosciences, University of Aberdeen, Aberdeen, Scotland
r.stephenson@abdn.ac.uk
and
Kenni D. Petersen, Søren B. Nielsen, Ole R. Clausen, Department of Earth Science, Aarhus University, Aarhus, Denmark

GeoConvention 2012:Vision

There is a widespread view within the exploration and academic geological communities that the existence and geometry of stratigraphic sequences and their bounding unconformities is eustasy-driven and globally correlative – though a background debate on the competing roles of tectonics and eustasy (particularly glacio-eustasy) has never completely subsided (as do the sedimentary basins themselves). The history of this debate and its role in sequence stratigraphy as well as its essential ingredients were summarised by Ashton Embry in Geo ExPro in 2006, with Ashton also describing his vision of how this debate would evolve in the future.

In his 2006 article, Ashton quoted Sloss and Speed (1974) as promoting "episodic changes in the proportion of melt in the asthenosphere below the continents" as a driving mechanism for generating sequence boundaries. Recently, we demonstrated that something akin to Sloss and Speed's prescient vision is very likely the case (Petersen et al., 2010). Our numerical models show that small-scale mantle convection can cause the development of stratigraphic sequences. Cyclic vertical surface displacements are predicted that occur at periods of 2 to 20 million years and correlate at distances up to a few hundred kilometres. The model considers not just the lithosphere but also the upper mantle, including the asthenosphere. Its parameters are fully consistent with established knowledge regarding rheology and heat transfer in the Earth.

The figure shows a rifted sedimentary basin formed by an imposed extension of 60 km; the basin evolves to be 300 km wide, with initial fault-controlled subsidence followed by thermal and loading-induced subsidence, as in any standard model. However, the feedback processes established between mantle thermal dynamics and lithosphere thinning result in periods of enhanced and decreased subsidence that produce cyclic patterns of transgression and regression and, accordingly, unconformities, accompanied by lateral migration of sedimentary facies.

In our model, it follows, unconformity bounded sequences are a natural consequence of mantle dynamics at rifted margins, indeed a natural consequence of the processes that produce and control the evolution of the sedimentary basins themselves. Although such T-R sequence boundaries may well be correlatable as (approximate) isochronous surfaces within basins, or within segments of a conjugate rifted margin system, it is not supportable to consider that they represent global (e.g. glacio-eustatic) or plate-wide (e.g. tectonically-induced lithospheric stress changes) events.

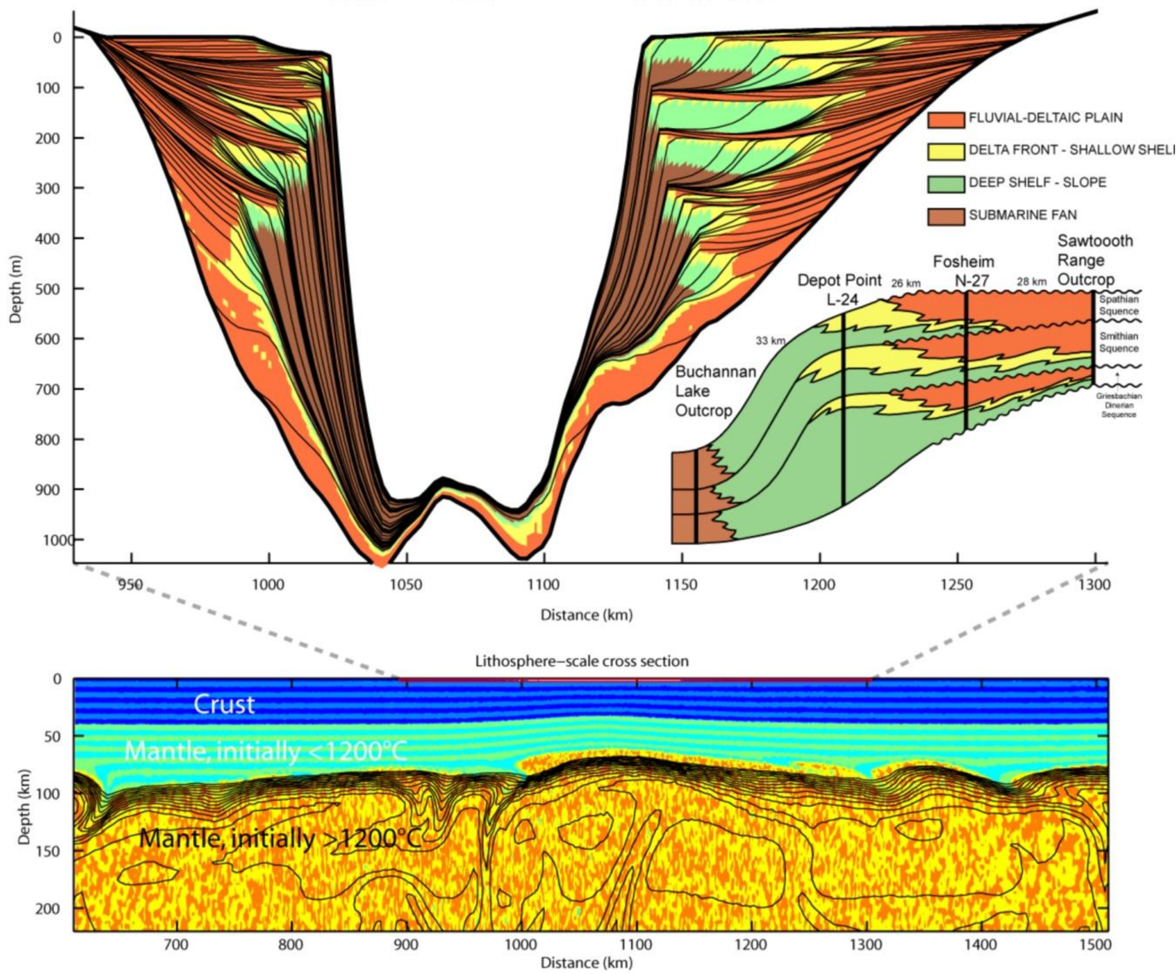

Figure 1: An example of a rift model (bottom panel) with small-scale convection and constant sediment input and (upper panel) lithofacies, represented by colour-coded paleo water depth, predicted by this model on the margins of the same rift. The inset on the upper panel is a section of the Sverdrup Basin from Embry (2009) for comparison with the model predictions. The figure is modified from Petersen et al. (2010).

References

Embry, A., 2006. Episodic Global Tectonics: Sequence Stratigraphy Meets Plate Tectonics: GEO ExPro (March 2006), 26-30.

Embry, A., 2009. Search and Discovery, www.searchanddiscovery.com/documents/2009/30105embry/

Petersen, K.D., S.B. Nielsen, O.R. Clausen, R. Stephenson and G. Taras, 2010. Small-scale sub-lithospheric convection produces stratigraphic sequences in sedimentary basins, Science, **329**, 827-830. DOI: 10.1126/science.119011

Sloss, L.L. and Speed, R.C., 1974. Relationships of cratonic and continental-margin tectonic episodes. Soc. Econ. Paleont. Mineral., Spec. Publ., **22**: 98-119.