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See table of contents

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Tectonics and Seismic Sequence Stratigraphy

Edited by G.D. Williams and A. Dobb
Geological Society, London, Special Publication 71, 226 p., 1993, US $75.00/£45.00

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The current vigorous debate surrounding the subject of sequence stratigraphy includes several major themes. One of these involves the need to develop precise chronostratigraphic frameworks in order to test Peter Vail's paradigm of high-frequency global eustasy (10^6-year episodicity). Some of the new research in this area was published in an earlier *Geological Society of London Special Publication (No. 70: High resolution stratigraphy)* reviewed by this writer in an earlier edition of *Geoscience Canada* (v. 20, p. 35-36). Another major theme is the attempt to assess the relative importance of regional and local tectonism as an alternative to eustasy in the generation of base-level changes and the resulting stratigraphic architectures. An important earlier work in this area was *International Association of Sedimentologists, Special Publication No. 12: Sedimentation, tectonics and eustasy*, edited by D.I.M. Macdonald. The present volume is another collection of research papers dealing with this theme.

The origins of the book are not at all clear. There is no preface or foreword that explains the genesis of the book as, for example, the product of a research symposium. Unlike Macdonald's book, however, one of the editors provides a useful introductory, overview paper on the theme of the book. Even here, though, the author, G.D. Williams, has missed an opportunity to pull together the research he and Dobb collected, in that he has not made any references to the papers in the volume. His review is a general discussion on the theme of regional and local tectonism (foreland fold-thrust development, rift and wrench faulting) that makes reference to much of the recent research in regional seismic-stratigraphic analysis, and is accompanied by several useful, clear diagrams that will probably make their way into many undergraduate courses. There is little beyond 1988, though, and therefore no references to Macdonald's book.

There are eight research papers in this book. All but one are of British origin, and all but two deal with the North Sea Basin or the types of problem generated by analysis of North Sea tectonism and sedimentation, such as the mechanics and stratigraphic effects of extensional block faulting. By focussing on the North Sea, the book makes a useful complement to the "active-margin" basins that were the main focus of Macdonald's book.

The first paper, by J.A. Cartwright and co-workers, examines the generation and preservation of sequence boundaries, and their recognition in the seismic record. This is a very useful study. It points out the much greater degree of stratigraphic resolution obtainable with modern seismic data acquisition and processing techniques than were available when the Exxon seismic-sequence work was first published in the 1970s, and the implications this has for stratigraphic interpretation. One of the most important discoveries has been that stratigraphic relationships that appear simple on older records are now revealed, in many cases, to be of considerable complexity. Many seismsic reflection terminations (onlaps, offlaps, toplaps, *etc.*), geometric features of such importance in stratigraphic analysis, can now be seen to be, in fact, a lateral thinning down to thicknesses that were formerly unresolvable. Sediments immediately below and beyond such terminations may, therefore, be of the same age as the apparently terminated unit. This could cause serious miscorrelation; for example, where scattered well records are used to date important onlap relationships as documentation of base-level rise. It also makes the exercise of correlation, or "forcing through" of sequence boundaries from seismic cross-section to cross-section — an essential element in the development of regional sequence frameworks — a much more difficult process. The authors point out that in many cases, such as in alluvial and coastal environments, depositional dips of such features as channels and beaches are much steeper than that of regional onlap/offlap slopes, such as the slope of typical continental shelves. In such cases, the actual stratigraphic generation of onlap is unlikely to be simple enough to be readily identified on seismic records.

The next paper, by S. Prosser, examines the depositional systems that develop in rift basins. By reference to recent work in North Sea and modern East African rifts, Prosser demonstrates that tectonisms can easily outpace eustasy (contrary to Vail, Jervey, Posamentier and the other members of the Exxon "eustasy" school). Prosser develops models for "tectonic systems tracts", which bring together data on structural and stratigraphic geometry, predicted gross stratigraphic composition and seismic expression. Most of this is hypothetical, but a few useful seismic examples serve to illustrate the main points.

D. Waltham and his co-workers examine "Sediment geometries and domino faulting", and develop a computer-simulation forward model based on North Sea data. They then use these data to generate synthetic seismic sections for comparison with real North Sea records. As with all such modelling experiments, the exercise provides an excellent opportunity to test the level of understanding of the processes involved, and the accuracy of the quantitative information used as input to the models.

Another model of fault-block subsidence and rotation is presented in the next paper, by A.M. Roberts and coworkers. This paper examines questions of scale and evolution of depositional systems, and the resolution of stratigraphic and structural information in seismic records.

Joy's paper, which follows, addresses a well-known anomaly in the North Sea Basin, that subsidence rates actually increased in the Paleocene, contrary to the expectations of the simple asymptotic stretching-cooling models that are usually applied to this basin (*e.g.*, Sclater and Christie, following Mackenzie). The last major rifting episode in the basin occurred in the Late Jurassic, whereas extensional faulting continued through the rest of the Mesozoic, and thermal subsidence should have slowed to insignificance by the beginning of the Cenozoic. Until the Paleocene, Joy points out, the central and northern North Sea rifts were relatively narrow, with subsidence of the rift shoulders proceding slowly, similar to many intracontinental rifts, such as the

Rhine graben. Accelerated subsidence in the Paleocene is attributed by Joy to an affect of the opening of the nearby North Atlantic Ocean and the transition of the rifts from an intracontinental to a continental-margin setting. Although not specifically addressed, this appears to this reader as an example of the effects of changing intraplate stress of the type so well described by Cloetingh and co-workers in several recent papers.

Another modelling paper follows. This one is by Higgs and McClay, and specifically addresses the structural style of the Outer Moray Firth, off northern Scotland. This is an important area, containing several major oil fields. The authors conclude that the fault style suggests an origin by the gravitational collapse of a regionally tilted sequence.

The last two papers seem a little out of place in this particular book, coming as they do after a suite of North Sea studies. That by Light and co-workers provides a regional stratigraphic-structural analysis of offshore Namibia, nicely illustrated with many coloured maps and sections. The main connection with the earlier papers would seem to be that this area began in much the same way as the North Sea, as a rift between two major continental blocks. In this case, of course, development proceeded to form a fully mature rifted Atlantic-type margin.

The final paper discusses the relationship between thrust tectonics and sequence stratigraphy in the Pyrenees. This is an interesting topic, and the Pyrenean foreland basins have been the subject of several important recent studies by Puigdefabregas, Burbank, Luterbacher and their various co-workers. Much useful data are presented here, but the paper is flawed from the outset, in this writer's view, by the author's correlation of their succession with the Exxon global cycle chart as the starting point of their analysis. In their abstract, they state, "The apparent correlation between the two groups of independent phenomena is an artefact of the method which calibrates the tectonic evolution by comparison with eustatic fluctuations". Well, yes. I think this is called circular reasoning.

One of the main conclusions this reader has reached after reading recent research focussing on the North Sea is that the North Sea Basin was a very poor choice for any stratigraphic templates to be used in establishing the record of global eustasy. Early work by Vail, including that by Vail and Todd published in 1981, made it clear that North Sea stratigraphy was serving as one of his major control points, particularly for the establishment of the Jurassic record. However, stratigraphic and structural work by such researchers as Hallam, Surlyk, Badley and recently, Underhill, has demonstrated the ubiquity of extensional and strike-slip faulting in this basin, and has also demonstrated that tectonism here, throughout the Mesozoic, was far from the slow background effect so preferred by the Exxon school.

For those concerned with the various sequence-stratigraphy debates, this will be a useful book, containing much ammunition and food for thought. As usual with the Geological Society of London productions, it is well edited, nicely printed and bound, and an altogether handsome product at a handsome price. See if you can find it on the reference shelf of your institute library, unless, of course, your sequence work provides you with tax write-offs to spend on things like this.