The Nature and Origin of Compression in Passive Margins

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The Nature and Origin of Compression in Passive Margins

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Preface

The tectonic evolution of passive continental margins is a topic not only of fundamental scientific interest, but also has relevance to various commercial developments, not least of which is the exploration and development of oil and gas resources. Increasingly, researchers have reported that passive margins do not show a simple uninterrupted thermal sag pattern of post-rift subsidence following continental separation as predicted by the McKenzie model for sedimentary basin development. Rather, the structural and stratigraphic development of such margins may record evidence of complex phases of differential subsidence and/or exhumation and fold development. Consequently, some passive margins have been considered to be 'anything but passive'. There are many ways in which post-breakup tectonism on passive margins can significantly affect petroleum systems. Some effects may be positive with respect to petroleum prospectivity, such as the development of large trapping structures. For example, some structural domes form major oil and gas fields, such as the Ormen Lange gas field offshore Norway, and others form possible future exploration targets. However, other effects may be negative with respect to petroleum prospectivity, such as uplift, trap tilting, fault reactivation, seal breach, and late timing of the structuring with respect to source rock maturation. Some of the fold structures observed on passive continental margins appear to be related to regional stresses transmitted through basement rocks, whereas others are related to gravitational sliding and toe-thrusting. Especially on volcanic passive margins, morphologically similar, but generically quite separate types of fold structures occur that are related to igneous intrusion or the emplacement of remobilized crust or magmatically underplated material at depth. This special publication concentrates on the first of these categories, that is compressive structures that appear to have formed on passive margins in the absence of an obvious gravitational sliding regime. The volume is derived from a joint Petroleum Group/Tectonic Studies Group 2-day international conference 'Compressional deformation within passive margins: nature, causes and effects' which was held at the Geological Society, London in October 2005.

The first section of the volume consists of three regional overview papers that consider the fundamental driving mechanisms that have been proposed to account for the generation, location and orientation of post-breakup compressional structures. A common theme in these papers is their emphasis upon the importance of structural inheritance through the reactivation of pre-existing structural architecture, which commonly exerts a strong local influence on the location and orientation of subsequent fold development. The relative merit of the potential driving mechanisms on the volcanic margin of the NE Atlantic is discussed by **Doré *et al***. They present the results of interdisciplinary studies to provide an introduction to the topic of post-breakup compression on passive margins in general before going on to review the complex nature, timing and distribution of post-breakup fold development on the NE Atlantic passive margin in particular. They recognize the importance of a number of primary and secondary driving mechanisms and also present some interesting new ideas on the potential importance of body force exerted by the Iceland Insular Margin, and on the factors governing location of the structures. **Cloetingh *et al.*** use examples from European passive margins and rifts to demonstrate that polyphase deformation of a compressional nature is a common feature in their post-rift evolution. The mode of compressional deformation appears to be strongly affected by the rheological structure of the underlying lithosphere and is characterized by a spectrum of spatial wavelengths spanning several tens of kilometres up to several hundreds of kilometres and by substantial differential vertical motions and late-stage anomalies in subsidence and uplift patterns. **Hillis *et al.*** summarize and compare present-day intraplate stresses, seismicity and neotectonic deformation in the Australian continent, focusing on its passive margins, in order to evaluate the extent to which this deformation can be accounted for in terms of the boundary forces acting on the plate. They argue that plate boundary forces are effectively transmitted thousands of kilometres into the Australian plate's interior where they are responsible for intraplate deformation.

The next section of this volume comprises four papers that examine post-breakup compression and uplift along the NE Atlantic margin and the Irish Sea. **Holford *et al.*** present a synthesis of extensive apatite fission-track analysis, vitrinite reflectance and a compaction database derived from sonic velocity and density log-derived porosities to demonstrate kilometre-scale Neogene exhumation driven by compressional deformation in the Irish Sea basin system. This interpretation contrasts with many previous studies which have attributed the exhumation of this region to processes

associated with the early Palaeogene initiation of the Iceland Plume. **Ritchie *et al.*** describe the effects of Cenozoic compression within the Faroe–Shetland Basin and surrounding areas, which are mainly manifested in the form of growth folds. Evidence is presented for a number of pulses of compression. Raised sea bed profiles over some of the anticlinal features may suggest that the effects of compressional stress continue into Pliocene to Recent times. **Smallwood** presents a Cenozoic topographic model for the Faroe–Shetland Basin that takes account of permanent uplift from igneous underplating, which is computed from gravity anomaly data, transient regional uplift and a simple elevation-dependent erosion term, under isostatic balance. The sediment volume balance suggests that around thirty per cent of the Paleocene sediments currently in the basin were sourced from a westerly provenance area, the pre-basalt Faroes platform terrane or East Greenland. **Ziska *et al.*** interpret previously unreleased commercial seismic profiles within the region to the SW of the Faroe Islands and suggest that these ridges were primarily initiated by a transient rifting event in the early Paleocene and were subsequently modified by significant compressive phases.

The final section of the volume comprises three papers that examine various pure and applied aspects of post-breakup tectonism in the West Iberia and Australia regions. **Péron-Pinvidic *et al.*** use seismic reflection data to examine localized deformation on the West Iberia margin associated with Eocene and Miocene compressive tectonic events that probably resulted from collision between Iberia, Europe and Africa. **Keep & Harrowfield** present a synthesis of Neogene tectonism in the Browse and Bonaparte basins along Australia's North West Shelf and attempt to reconcile the growth of major Neogene depocentres with brittle normal faults in a convergent plate boundary setting. **Rogers *et al.*** utilize a geomechanical model of the *in situ* stress field, the mechanical properties of the fault rock and the orientations of existing faults to assess the propensity of fault reactivation within a proposed demonstration site for the subsurface geological storage of carbon dioxide located in southeastern Australia.

Any publication of this nature requires the help of a large number of people. We would like to thank the staff of the Conference Office at Burlington House for their help in organizing the meeting in October 2005, and the conference sponsors BP, Shell and Statoilhydro. We also thank staff of the Geological Society Publishing House for their assistance in producing the volume. Finally, we thank the following colleagues in the British Geological Survey, academia and industry who gave their time to review the papers published here: Andy Chadwick, Dave Ellis, Richard England, Neil Grant, Richard Hillis, Geoff Kimbell, David Moy, Emma Nelson, Kevin Smith and Ian Walker.

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