Introduction

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Passive margins

Passive margins evolve by rifting of continental plates, rupture and separation that forms new plate boundaries and new oceanic basins. Ancient and modern plate margins have long been a focus of discovery, research and exploration for resources.

Present day passive margins form the greater part of the world’s continental margins. They extend on both sides of the Atlantic Ocean, surround much of the African, Australian and Antarctic continents and form both Indian margins as well as much of the circum Arctic margins (Fig. 1). In this volume key studies are presented from Central and South Atlantic margins, the eastern Indian margin and the NW Shelf of Australia as well as from the eastern Mediterranean (Fig. 1).

Many passive margins, such as the Gulf of Mexico, offshore Brazil (Fig. 1), as well as the Angolan and Congo margins, also contain either pre- and or post-riift salt that dramatically affects their structural and stratigraphic architectures. The formation of passive margins may be influenced by many factors, including plate geodynamics, patterns of underlying mantle flow, inherited continental basement fabrics and discontinuities, extensional fault geometries and evolution of initial rift architectures, magmatic processes and breakup kinematics and timings, as well as sediment loads and their distributions during margin evolution. Recent studies and some chapters in this volume have been based on the ION Span deep seismic profiles acquired over many passive margins as well as new broadband 2D and 3D seismic surveys, particularly over the deep-water sectors of margins such as offshore Brazil (Rowan 2018; Tugend et al. 2018) and offshore West Africa (Scarselli et al. 2018).

This volume of 16 papers is in honour of the late Professor David Roberts, who made significant contributions to understanding of the development of passive margins and their sedimentary basins.

The introduction paper by Gerdes (2018) celebrates the life and contributions of Professor David Roberts to the study of passive margins from his days at the Institute of Oceanographic Studies to leading the basins studies group at BP, and lastly as a consultant and Visiting Professor at Royal Holloway, University of London, Institut Français du Pétrole and other universities. This first paper also outlines some of the history of the study of passive margins from the mid to latter part of the twentieth century and to the present day. In particular one should acknowledge David’s extremely fruitful collaborations with Professors Lucien Montadert and Pierre-Charles Graciansky as this partnership produced many of the first modern insights into passive margin systems (e.g. Graciansky et al. 2011; also see references in Gerdes 2018). These studies focused in particular on the structure of the Iberian margin and the importance of comparisons with field examples of the exposed Tethyan passive margins preserved in the western Alps. Many of the more recent studies of passive margins have built upon these earlier insights into passive margin evolution (e.g. Lavier & Manatschal 2006; Mohn et al. 2012; Péron-Pinvidic et al. 2013, 2015; Manatschal et al. 2015; Osmundsen & Péron-Pinvidic 2018).

Structure of passive margins

The broad classification of passive margins into magma-poor and magma-rich archetypes is reviewed by Tugend et al. (2018). These authors analyse two ION Span deep seismic reflection profiles – one offshore eastern India (magma poor) and the other offshore Uruguay (magma-rich), in order to study the nature and magmatism of the transition from stretched continental to proto-oceanic and to oceanic crust. They conclude that the mechanics of lithospheric breakup for both archetypes are essentially similar but differences in the timing of onset of decompression melting and magmatism may
Fig. 1. World digital elevation model showing the focus areas for the papers in this volume. The papers are shown by numbers 2–16 in order of appearance in this volume. Regions of oceanic crust are shown in shades of blue to purple with the trenches of subduction systems highlighted by narrow elongate zones of intense purple colour. The colours for continental terranes vary from low elevation greens and yellows to greys and reds at the highest elevations (e.g. Himalayas). 2, Tugend et al.; 3, Khalil & McClay; 4, Kusznir et al.; 5, Scaselli et al.; 6, Perez-Diaz & Eagles; 7, Tamara et al.; 8, Restrepo-Pace; 9, McCormack & McClay; 10, Bilal & McClay; 11, Deng & McClay; 12, Dooley et al.; 13, Pindell et al.; 14, Rowan; 15, Jagger et al.; 16, Llave et al. Global DEM data courtesy of NASA.
generate different archetypal geometries and kinematics. Three possible interpretations and models for the architecture of lithospheric breakup are presented for each margin studied. Passive margin models from this research group (e.g. stylized in Fig. 2) are widely used as interpretational 2D templates for many recent passive margin studies (Péron-Pinvidic & Osmundsen 2018; Matthesch et al. 2015; Péron-Pinvidic et al. 2015; Osmundsen & Péron-Pinvidic 2018) as well as in papers presented in this volume (Restrepo-Pace 2018; Rowan 2018; Scarselli et al. 2018).

The second paper in this section (Khalil & McClay 2018) examines rift margin structures in the Northern Red Sea in Egypt as an example of the architecture of the inboard rift basin systems that occur on many passive margins. Passive margins commonly evolve from continental rift basins, and the structures formed at these early stages of extension prior to breakup are inherited as the passive margin evolves. The field examples illustrate the complex fault linkages between segmented and en-echelon rift faults (Fossen & Rotevatn 2016) as well as associated extensional folding in segmented rift half-grabens. These types of fault architectures are likely to also be found in other rifts (e.g. Henstra et al. 2015), as well as in the marginal basins of many passive margins (e.g. Northwest Shelf of Australia, Deng & McClay 2019).

**Central and South Atlantic margins**

The Atlantic margins have long been studied as type examples of passive margins, particularly in the context of the formation of conjugate margins such as those offshore Iberia–offshore Newfoundland (Péron-Pinvidic et al. 2013). Papers in this section focus mainly on the Equatorial Atlantic margins (Kusznir et al. 2018; Scarselli et al. 2018; Tamara et al. 2020), but also include the development of palaeobathymetry in the South Atlantic realm (Pérez-Díaz & Eagles 2018) and the shelf tectonics of the Niger delta system (Restrepo-Pace 2018; see Fig. 1).

Kusznir et al. (2018) use regional-scale gravity inversion of the equatorial Atlantic region to map the 3D crustal thickness from the continental margins to the oceanic basins. In a series of regional maps and cross-sections they show depth to Moho and total crustal thicknesses including continental and oceanic, residual continental crustal thicknesses as well as continental lithosphere stretching and thinning factors. Using G Plate reconstructions they demonstrate that the Equatorial Atlantic opened using a series of stepped transform-rift segments that gave rise to variable crustal architectures along both the Brazilian and West African margins. The results from the gravity inversion and their crustal cross-sections are validated by strong agreement with published crustal cross-sections derived from wide-angle seismic studies. In particular this research highlights the anomalous crustal thicknesses encountered along transform margins. Gravity inversion results can be an important input into continental margin studies and plate reconstructions, for regional palaeogeographical reconstructions and palaeoheat flow predictions. The authors demonstrate that gravity inversion can be a valuable tool for deep-water basin analysis and may be applicable to other passive margins, particularly where there is little other data available.

Scarselli et al. (2018) analyse a modern depth migrated 3D broadband seismic volume offshore Côte d’Ivoire to determine the tectono-stratigraphic evolution and the deep structure underlying this part of the equatorial margin of West Africa (Fig. 1). Deep-rotated fault blocks with hanging-wall Aptian to Albian fanning growth strata, in places exceeding 3.5 km thickness, detach on a low-angle basal detachment. Aptian–Albian sill complexes are developed as well as prominent volcanic complexes that together form a widespread igneous province. Significant ridges occur perpendicular to the main extensional fault trends and these are interpreted to result from lateral movements owing to the proximity of the transform systems that occur in this region. The authors interpret the deep structure to be in the hyper-extensional to exhumed domains (similar to the model shown in Fig. 2) with transform elements and associated igneous intrusions and volcanic edifices. The results indicate that the development of the equatorial margin of West Africa may have initiated in the Aptian and the deep structures are not simply cylindrical but vary significantly along-strike and thus illustrate the necessity of deep 3D seismic data on order to fully characterize passive margins with oblique and transform elements.

Palaeobathymetric reconstructions from the Early Cretaceous of the South Atlantic basins (Fig. 1) are presented by Pérez-Díaz & Eagles (2018). The methodology incorporates oceanic-age grids, satellite gravity data, dynamic topography and sediment thickness distributions and ages in order to calculate the depths of basement and oceanic crust at time slices for the South Atlantic evolution. Comparisons with measured palaeobathymetries from drill sites indicate that this method is accurate to within 700 m over large parts of the deep ocean to but less so near large igneous provinces and at earlier time periods. These reconstructions have significant implications for palaeo-oceanographic studies and the prediction of palaeodepositional environments on passive margins, and the methodology can be applied to other passive margins.
Fig. 2. Synoptic and schematic 2D lithospheric model of a passive margin based on Osmundsen & Péron-Pinvidic (2018) and Péron-Pinvidic & Osmundsen (2018). This figure summarizes some of the main elements of many passive margins. Individual passive margins may vary greatly along-strike and not display all of these elements in every 2D section. (a) *Proximal domain* – the inboard rift fault systems with syn-rift sediments in hanging-wall basins; (b) *necking domain* – greater extension and rotation of crustal fault blocks – ductile stretching in the lower crust; (c) *distal – hyper-extension domain* – an outer domain of highly extended and rotated crustal blocks with very low angle to horizontal detachment faults. Large displacements and highly thinned lower crust; (d) *distal – exhumed domain* – an outer domain of highly extended boudinaged crust in places riding on exhumed continental mantle; (e) *outer domain – break up zone* with igneous intrusions (dykes and sills) as well as seaward-dipping reflectors formed by lava flows and volcanoclastic wedges that dip oceanward; continent–ocean boundary; (f) *Oceanic domain* – thin high-velocity oceanic crust commonly with a well-defined seismic Moho (e.g. figures in Tamara *et al.* 2020).
The crustal architecture of the central equatorial margin of northeastern Brazil is documented by Tamara et al. (2020) (Fig. 1). This oblique divergent margin is segmented by transform structures where the Saint Paul Fracture Zone impinges on the extensional sectors. Analysis of high-quality deep regional seismic lines has revealed distinct domains similar to those shown in Figure 2 but varying along the margin. In three dimensions along-strike there is an inboard rift domain, a necking domain passing to an outboard hyper-extension domain and exhumation domain transitioning to oceanic crust. The margin is steep with distinct gravity-driven slide complexes with linked updip listric extensional faults and downdip fold-and-thrust systems. Post-rift volcanic complexes are found in the exhumation and oceanic domains. The results of this study show that the architecture of this passive margin formed by the Cretaceous breakup of the Equatorial Atlantic varies significantly along-strike and evolutionary models need to be built on a number of seismic sections and not just on a single ‘hero’ line.

Progradational delta systems have formed on many passive margins such as those of the Mississippi delta on the Gulf of Mexico margin (Wu & Bally 2000), the Nile delta on the Mediterranean margin of Egypt and the Niger delta system offshore Nigeria, West Africa. They commonly contain significant hydrocarbon resources. Restrepo-Pace (2018) (Fig. 1) reviews the tectono-sedimentary evolution of the Niger delta and challenges the long-held model of ductile, overpressured shales (e.g. Cobbold et al. 2009) did not deform like salt by continuous internal plastic flow but instead deformed by brittle processes – coherent folding, extension and imbrication on discrete fault surfaces facilitated by high poro-fluid pressures (cf. Krueger & Grant 2013). This ‘brittle’ model has important implications for understanding the structural styles in shale-detached deltas, for section balancing and for models of trap formation, particularly in deep-water fold-and-thrust belts on passive margins as well as in accretionary prisms.

Northwestern Australian passive margin

The three papers in this group focus on structural styles on the NW Shelf passive margin of northern Australia (Fig. 1). This is a Mesozoic–Cenozoic passive margin that underwent Permo-Carboniferous rifting followed by Late Triassic–Late Jurassic rifting with Late Cretaceous breakup and Cenozoic thermal subsidence (Baillie et al. 1994; Longley et al. 2002; Heine & Müller 2005). It is a major hydrocarbon province with significant gas and oil accumulations (Longley et al. 2002).

The paper by McCormack & McClay (2018) is a detailed structural analysis of a high-quality 3D survey on the outer part of the Beagle Sub-Basin – an inboard rift basin on the NW Shelf passive margin. The complex fault architectures display a ‘pseudo conjugate’ pattern of horsts and grabens but are interpreted to be an orthorhombic strain pattern in keeping with the regional WNW extension direction as the passive margin developed in the Late Triassic through to the Early Cretaceous. This analysis shows that different orientations of extensional fault systems do not necessarily imply that the regional driving stresses have rotated but rather that complex fault geometries and ‘pseudo conjugate systems’ may be developed in a single, uniform regional stress field.

Bilal et al. (2018) describe the extensional fault systems in the Exmouth Plateau of the NW Australian passive margin. Here domino-style extensional faults display significant footwall uplift and rotation together with fault scarp degradation and retreat – in places up to 1.8 km. Detailed fault displacement analyses show a clear correlation between the maximum uplift, maximum fault displacements and maximum scarp retreat/degradation. In other rift basins such as the Central and Northern North Sea (e.g. Fraser et al. 2002; Welbon et al. 2007), fault scarp degradation significantly changes fault and footwall geometries as well as potential reservoir architectures and volumes. Fault scarp degradation, whether by erosion or gravitational collapse, is likely to be found in the inboard sectors of many passive margins in the marginal rift blocks and in the necking zones (e.g. Fig. 2).

The paper by Deng & McClay (2019) focuses on the tectono-stratigraphic development of the Dampier Sub-Basin in the NW Australian passive margin. This is a Late Triassic to Late Jurassic inboard, marginal rift basin that was controlled by an earlier Permo-Carboniferous rift system along the NW margin of Australia. A new tectono-stratigraphic model is presented for this inboard rift basin that formed as a result of WNW extension superposed on an older Late Paleozoic NE–SW rift system. This tectonic history generated en-echelon overlapping, segmented and complexly linked Mesozoic extensional faults. Similar fault architectures have been documented in the northern Red Sea (e.g. Khalil & McClay 2016, 2018) and the Norwegian margin (e.g. Henstra et al. 2015) and illustrate the
importance of understanding basement inheritance in both rifts and on passive margins.

Salt basins on passive margins

Many passive margins such as the northern Gulf of Mexico, the Campos and Santos basins offshore Brazil and the Angola and Congo basins of West Africa have significant salt basins that host major hydrocarbon resources (e.g. Heine et al. 2013; Hudec et al. 2013; Rowan 2014). Salt sections produce complex structures and strongly affect the stratigraphic architecture and sedimentation within passive margin basins.

Scaled physical modelling of salt tectonics has become the principal tool in understanding the progressive evolution of salt systems in basins as copiously illustrated in the outstanding text book by Jackson & Hudec (2017). Dooley et al. (2018) describe some stunning analogue model experiments that demonstrate how salt may flow up over ridges and over complex topography that can be developed in extensional basins on passive margins. These experiments applied to the eastern Gulf of Mexico demonstrate that inherited topography controls salt dynamics and the types of salt accumulations formed by downslope flow on a subsiding passive margin. The models can be compared with the sections shown in the papers by Pindell et al. (2018) and Rowan (2018) in this volume and provide insights into the progressive evolution of these systems.

Pindell et al. (2018) use regional deep seismic lines to demonstrate ‘outer margin collapse’ (e.g. Pindell et al. 2014) and its effects on the evolution of the mega-salt basins on the Florida passive margin of the eastern Gulf of Mexico, as well as on the Santos and Campos basins of eastern Brazil. They propose a multistage extension model for the initial rift phase with deposition at or near sea-level followed by a widespread sag phase in response to thermal subsidence. This is followed by incipient ‘breakup’ with extension focused on outer margin fault systems followed by margin collapse and initial salt deposition. At the breakup stage depth-dependent stretching and subsidence of the outer margin produce regional tilting into the basin. The post-rift sag strata and base of salt dip ocean-ward together with down-slope salt flow towards the newly formed spreading centre. This model and variations of it may account for the salt distributions on the Florida passive margin of the eastern Gulf of Mexico as well as the salt basin architectures in the South Atlantic salt basins.

The third paper in this section by Rowan (2018) examines the similarities shared by salt basins in the Gulf of Mexico with those in the South Atlantic. Rowan analyses the salt geometries with respect to the basement architectures formed in the necking zone at the transition from highly extended continental crust to fully developed oceanic crust. He concludes that the salt formed in isolated basins at or near sea-level and that subsequent hyper-extension resulted in large, deep underfilled depocentres with basin-ward flow of salt producing inflation and allochthonous salt, in places on top of the oceanic crust. Dooley et al. (2018) simulated similar features in the analogue models of salt flow into the basin.

Other margins

Jagger et al. (2018) present new models for the tectono-stratigraphic evolution of the SE Mediterranean basin offshore Libya, Egypt and Lebanon. This passive margin is segmented into both rift- and transform-dominated segments. The extensional fault systems are strongly influenced by repeated reactivation of Pan-African basement fabrics and shear zones, as shown by the inheritance of Neo-tethyan rift systems and their control on the Santonian–Maastrichtian and Mid-Eocene to Oligocene inversion events. This study gives insights into the complex transform components of passive margins as also seen in the Ghana–Côte d’Ivoire margin on the equatorial margin of West Africa (cf. Scarselli et al. 2018), as well as on the Brazilian margin (Tamara et al. 2020).

The development of contourite systems around the Iberian passive margins is reviewed by Llave et al. (2019). Contourites on passive margins are important potential new locations for hydrocarbon exploration. Using high-resolution seismic sections, this paper summarizes the key characteristics and architectures of contourites on the Atlantic margin of Iberia well as on the Mediterranean margin of Iberia. The models and examples of contourite depositional systems illustrated in this paper may be applied to other passive margins (e.g. South Atlantic), where they will be relevant to research as well as to exploration for new hydrocarbon reservoirs.

Summary

Passive margins are far from passive. They display a variety of dynamic structures developed during, as well as after, rifting, necking, thinning and breakup. These include hyper-extended crustal blocks, uplift and exposure of subcontinental mantle and stretching-related magmatism. Syn- and post-breakup loading by continental margin wedges, by progradational delta systems as well as by gravity-driven slide complexes from margin uplift and subsequent collapse substantially affect the architectures of many passive margins (cf. Pindell et al. 2014, 2018). It is noteworthy that most of the current models for passive margin evolution rely largely on 2D regional seismic
lines and relatively little is known about the 3D architectures along-strike, and 3D seismic data is needed particularly for oblique and transform margins (e.g. Scarcelli et al. 2018).

It is clear that in many margins inherited basement structures control the initial rift architectures (e.g. as in in the Gulf of Suez and Red Sea Bosworth et al. 2005; Khalil & McClay 2016, 2018) as well as other rift basins (Tvedt & McClay 2013; Henstra et al. 2015). These patterns are commonly reflected in the inboard structures of passive margins (e.g. Cobbold et al. 2001; Mohn et al. 2012). In particular the scales of rift margin uplift, syn- and post-rift exhumation and subsequent collapse into the evolving passive margin have not been widely studied. Invaluable insights have been gained from 2D deep reflection seismic profiles but future research on passive margins also needs to include 3D reflection seismic surveys. Results from such studies will need to be integrated with refraction, gravity and magnetic data in order to take the current 2D models (e.g. Fig. 2) into 3D, as recently shown for the distal Iberian margin by Lymer et al. (2019). Many passive margins are under-explored and new seismic and drilling data are much needed to improve current models for their evolution.

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References

Aikariye, D.E. & Bally, A.W. 2002. Manual and atlas of structural styles. Niger Delta. AAPG Continuing Education Course Notes Series, 41.

Bailie, P.W., Powell, C.McA., Li, Z.X. & Ryall, A.M. 1994. The tectonic framework of Western Australia’s Neoproterozoic to recent sedimentary basins. In: Purcell, P.G. & Purcell, R.R. (eds) The Sedimentary Basins of Western Australia: Proceedings of the Petroleum Exploration Society of Australia Symposium. Petroleum Exploration Society of Australia, Perth, 45–62.

Bilal, A., McClay, K. & Scarcelli, N. 2018. Fault-scarp degradation in the central Exmouth Plateau, North West Shelf, Australia. In: McClay, K.R. & Hammerstein, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.11

Bosworth, W., Huchon, P. & McClay, K. 2005. The Red Sea and Gulf of Aden basins. Journal of African Earth Sciences, 43, 334–378, https://doi.org/10.1016/j.jafrearsci.2005.07.020

Cobbold, P.R., Meisling, K.E. & Mount, V.S. 2001. Reactivation of an obliquely rifted margin, Campos and Santos basins, southeastern Brazil. AAPG Bulletin, 85, 1925–1944.

Cobbold, P.R., Clarke, J.B. & Loseth, H. 2009. Structural consequences of fluid overpressure and seepage forces in the outer thrust belt of the Niger Delta. Petroleum Geoscience, 15, 3–15, https://doi.org/10.1144/1354-079309-784

Deng, H. & McClay, K. 2019. Tectono-stratigraphy of the Dampier Sub-basin, North West Shelf of Australia. In: McClay, K.R. & Hammerstein, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476-2018-180

Doolay, T.P., Hedec, M.R., Pichel, L.M. & Jackson, M.P.A. 2018. The impact of base-salt relief on salt flow and supra-salt deformation patterns at the autochthonous, paraautochthonous and allochthonous level: insights from physical models. In: McClay, K.R. & Hammerstein, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.13

Fosse, H. & Rotevatn, A. 2016. Fault linkages and relay structures in extensional settings – a review. Earth Science Reviews, 154, 14–28, https://doi.org/10.1016/j.earscirev.2015.11.014

Fraser, S.I., Robinson, A.M. et al. 2002. Upper Jurassic. In: Armour, A., Evans, D. & Hickey, C. (eds) The Millennium Atlas: Petroleum Geology of the Central and Northern North Sea. The Geological Society, London, 157–189.

Gorges, K.D. 2018. Professor David Gwyn Roberts – a Life in Geoscience. In: McClay, K.R. & Hammerstein, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.7

Graciansky, P.C., Roberts, D.G. & Tricart, P. 2011. The Western Alps, from Passive Margin to Orogenic Belt. Developments in Earth Surface Processes, 14.

Heine, C. & Muller, R.D. 2005. Late Jurassic rifting along the Australian North West Shelf: margin geometry and spreading ridge configuration. Australian Journal of Earth Sciences, 52, 27–39, https://doi.org/10.1080/0812009050010077

Heine, C., Zoethout, J. & Muller, R.D. 2013. Kinematics of the South Atlantic rift. Solid Earth, 4, 215–253, https://doi.org/10.5194/se-4-215-2013
HENSTRA, G.A., ROTEVATN, A., GAWTHORPE, R.L. & RAVNÁS, R. 2015. Evolution of a major segmented normal fault during multistage rifting: the origin of plan-view zigzag geometry. Journal of Structural Geology, 74, 45–63, https://doi.org/10.1016/j.jsg.2015.02.005

HUDEC, M.R., NORTON, I.O., JACKSON, M.P.A. & PEELE, F.J. 2013. Jurassic evolution of the Gulf of Mexico salt basin. AAPG Bulletin, 97, 1683–1710, https://doi.org/10.1306/0401132073

JACKSON, M.P.A. & HUDEC, M.R. 2017. Salt Tectonics: Principles and Practice. Cambridge University Press, Cambridge.

JAGGER, L.J., BEVAN, T.G. & MCCLAY, K.R. 2018. Tectono-stratigraphic evolution of the SE Mediterranean passive margin, offshore Egypt and Libya. In: MCCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.10

KHALIL, S.M. & MCCLAY, K.R. 2016. 3D Geometry and kinematic evolution of extensional fault-related folds, northwestern Red Sea, Egypt. In: CHILD, C., HOLDSWORTH, R.E., JACKSON, C.A.-L., MANZOCCHI, T., WALSH, J.J. & YELDING, G. (eds) The Geometry and Growth of Normal Faults. Geological Society, London, Special Publications, 439, 109–130, https://doi.org/10.1144/SP439.11

KHALIL, S.M. & MCCLAY, K.R. 2018. Extensional fault-related folding in the northwestern Red Sea, Egypt: segmented fault growth, fault linkages, corner folds and basin evolution. In: MCCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.12

KRUEGER, W.S. & GRANT, N.T. 2013. The growth historical of toe thrusts of the Niger Delta and the role of pore pressure. In: MCCLAY, K., SHAW, J. & SUPPE, J. (eds) Thrust Fault-Related Folding. American Association of Petroleum Geologists, Memoirs, 94, 357–390.

KUSSNIJK, N.J., ROBERTS, A.M. & ALVEY, A.D. 2018. Crustal structure of the conjugate Equatorial Atlantic Margins, derived by gravity anomaly inversion. In: MCCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.5

LAVIER, L.Y. & MANATSCHAL, G. 2006. A mechanism to thin the continental lithosphere at magma-poor margins. Nature, 440, 324–328; https://doi.org/10.1038/nature04608

LLAVE, E., JAVIER HERNÁNDEZ-MOLINA, F. ET AL. 2019. Contourites along the Iberian continental margins: conceptual and economic implications. In: MCCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476-2017-46

LONGLEY, I. & BUSSENSCHUETZ, C. ET AL. 2002. The North West Shelf of Australia – a Woodside perspective. In: KEEP, M. & MOSS, S. (eds) The Sedimentary Basins of Western Australia 3: Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, Australia. Petroleum Exploration Society of Australia, Perth, 27–88.

LYMER, G., CRESSWELL, D.J.F. ET AL. 2019. 3D development of detachment faulting during continental breakup. Earth and Planetary Science Letters, 515, 90–99, https://doi.org/10.1016/j.epsl.2019.03.018

MANATSCHAL, G., LAVIER, L. & CHENIN, P. 2015. The role of inheritance in structuring hyperextended rift systems: some considerations based on observations and numerical modeling. Gondwana Research, 27, 140–164, https://doi.org/10.1016/j.gr.2014.08.006

MCCORMACK, K.D. & MCCLAY, K.R. 2018. Orthorhombic faulting in the Beagle Sub-basin, North West Shelf, Australia. In: MCCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.3

MOHN, G., MANATSCHAL, G., BELTRANDO, M., MASINI, E. & KUZNIK, N. 2012. Necking of continental crust in magma-poor rifted margins: evidence from the fossil Alpine Tethys margins. Tectonics, 31, TC1012, https://doi.org/10.1029/2011TC002961

OSMUNDSEN, P.T. & PÉRON-PINVIDIC, G. 2018. Crustal-scale fault interaction at rifted margins and the formation of domain-bounding breakaway complexes: insights from offshore Norway. Tectonics, 37, 935–964, https://doi.org/10.1002/2017TC004792

PEREZ-DIAZ, L. & EAGLES, G. 2018. Estimating palaeobathymetry with quantified uncertainties: a workflow illustrated with South Atlantic data. In: MCCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.1

PÉRON-PINVIDIC, G., MANATSCHAL, G. & OSMUNDSEN, P.T. 2013. Structural comparison of archetypal Atlantic rifted margins: a review of observations and concepts. Marine and Petroleum Geology, 43, 21–47, https://doi.org/10.1016/j.marpetgeo.2013.02.002

PÉRON-PINVIDIC, G., MANATSCHAL, G., MASINI, E., SUTRA, E., FLAMENT, J.M., HAUPERT, I. & UNTERNEHR, P. 2015. Unravelling the along-strike variability of the Angola–Gabo rifted margin: a mapping approach. In: SARATO CERALDI, T., HODGKINSON, R.A. & BACKE, G. (eds) 2017. Petroleum Geoscience of the West Africa Margin. Geological Society, London, Special Publications, 438, 49–76, https://doi.org/10.1144/SP438.1

PÉRON-PINVIDIC, G. & OSMUNDSEN, P.T. 2018. The Mid Norwegian –NE Greenland conjugate margins: rifting evolution, margin segmentation, and breakup. Marine and Petroleum Geology, 98, 162–184, https://doi.org/10.1016/j.marpetgeo.2018.08.011

PINDELL, J., GRAHAM, R. & HORN, B.W. 2014. Rapid outer marginal collapse at the rift to drift transition of passive margin evolution, with a Gulf of Mexico case study. Journal of Basin Research, 26, 1–25 https://doi.org/10.1111/jbr.12055

PINDELL, J., GRAHAM, R. & HORN, B.W. 2018. Role of outer marginal collapse on salt deposition in the eastern Gulf of Mexico, Campos and Santos basins. In: MCCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism.
INTRODUCTION

Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.4

RESTREPO-PACE, P.A. 2018. ‘Ductile v. Brittle’ – alternative structural interpretations for the Niger Delta. In: McCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.2

ROWAN, M.G. 2014. Passive-margin salt basins: hyperextension, evaporite deposition, and salt tectonics. Journal of Basin Research, 26, 154–182, https://doi.org/10.1111/jbre.12043

ROWAN, M.G. 2018. The South Atlantic and Gulf of Mexico salt basins: crustal thinning, subsidence and accommodation for salt and presalt strata. In: McCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.6

SCARSELLI, N., DUVAL, G., MARTIN, J., McCLAY, K. & TOOTHILL, S. 2018. Insights into the Early Evolution of the Côte d’Ivoire Margin (West Africa). In: McCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.8

TAMARA, J., McCLAY, K. & HODGSON, N. 2020. Crustal structure of the central sector of the NE Brazilian equatorial margin. In: McCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476-2019-54

TUGEND, J., GILLARD, M. ET AL. 2018. Reappraisal of the magma-rich v. magma-poor rifted margin archetypes. In: McCLAY, K.R. & HAMMERSTEIN, J.A. (eds) 2020. Passive Margins: Tectonics, Sedimentation and Magmatism. Geological Society, London, Special Publications, 476, https://doi.org/10.1144/SP476.9

TVEDT, A.B.M., ROTEVATN, A., JACKSON, C.A.L., FOSSEN, H. & GAWTHORPE, R.L. 2013. Growth of normal faults in multilayer sequences: a 3D seismic case study from the Egersund Basin, Norwegian North Sea. Journal of Structural Geology, 55, 1–20, https://doi.org/10.1016/j.jsg.2013.08.002

WINTER, R.W., MANN, M.G., ANGELICH, M.T. & MOLYNEUX, I.B. 2010. Mobile Shale in the Niger Delta: Characteristics, Structure, and Evolution. American Association of Petroleum Geologists, Memoirs, 95, 145–161.

WOOD, L. (ed.) 2010. Shale Tectonics. American Association of Petroleum Geologists, Memoirs, 95.

WELBON, A.I.F., BROCKBANK, P.J., BRUNSDEEN, D. & OLSen, T.S. 2007. Characterizing and producing from reservoirs in landslides: challenges and opportunities. In: JOLLEY, S.J., BARR, D., WALSH, J.J. & KNIPE, R.J. (eds) Structurally Complex Reservoirs. Geological Society, London, Special Publications, 292, 49–74, https://doi.org/10.1144/SP292.3

WU, S. & BALLY, A.W. 2000. Slope tectonics – Comparison and contrasts in structural styles of salt and shale tectonics in the Gulf of Mexico with Shale Tectonics in the Niger Delta in the Gulf of Guinea. American Geophysical Union, Geophysical Monographs, 115, 151–172.