Structural Geology in Reservoir Characterization

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Structural Geology in Reservoir Characterization

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Preface

This volume is for geologists, geophysicists and reservoir simulation/petroleum engineers studying faulted and fractured reservoirs, particularly those interested in studying petroleum traps, predicting fluid flow or modelling structurally heterogeneous reservoirs.

The two main aims of the volume are to capture the wide range of rapidly expanding research in this area, which reflects the increasing importance of comprehensive 'structural characterization' in static reservoir descriptions, and to help promote synergy between the geosciences and petroleum engineering disciplines. The first aim is addressed by the sixteen papers of the volume, the majority of which cover a range of structural geological features, particularly faulted and fractured reservoirs, fault gouge properties, fault seal potential and fluid flow/simulation modelling in faulted and fractured reservoirs. The papers draw heavily on experience obtained in the North Sea.

The first two papers set the theme of the subject area. The remainder of the book is divided into two parts: faults and fractures (ten papers), and case studies (four papers).

In the introduction, **Cosgrove** reviews the role of structural geology in reservoir characterization and contrasts traditional aspects of structural geology, which focused on the three-dimensional geometry and spatial distribution of structures, with recent trends, which consider the dynamics of structure formation and the interplay of stress and fluid migration.

This is complimented by **Archer**, who provides a broad, petroleum engineering view of reservoir characterization, covering both static description and dynamic modelling aspects, and reviews some of current industry challenges in field development and reservoir management.

The majority of the volume is devoted to various aspects of faults and fractures. **Freeman *et al.*** present a methodology for predicting fault seal potential, the Gouge Ratio method, which integrates seismically based geometrical data with well-based lithological and compositional information. Application of this method in the Oseberg South field is demonstrated. Experimental aspects of fault plane characteristics are considered by **Crawford**, who quantifies the magnitude of permeability reduction in a series of experiments on artificially-induced shear bands.

Gabrielsen *et al.* emphasize the importance of evaluating the complete fracture system in subsurface structural reservoir characterization, including the full deformation history, lithology (grain size, composition, bed thickness, etc.), rheological properties and the relationship of the well under investigation to nearby larger structures. The impact of fault geometries on compartmentalization, effective permeability and fluid flow in high porosity sandstones has been assessed by **Manzocchi *et al.*** in a series of numerical flow simulations. **Gibson** also considers faulted sandstone reservoirs and emphasizes the importance of understanding the nature (e.g. lithology, composition, clay content, etc.) and fluid flow properties (e.g. permeability and capillary displacement pressures) of the sandstone-derived fault zones, of which two main types are highlighted: deformation bands, derived from quartz-rich sandstones, and clay matrix gouge zones, derived from mineralogically immature sandstones. **Walsh *et al.*** present a range of fault and fault array models, to investigate the impact of variations in fault density, spatial distribution, orientation distribution and fault zone permeability (relative to the bulk permeability of the host rock) on the overall single phase horizontal bulk permeability of a typical North Sea Brent Group reservoir. Results demonstrate that fault densities are much more significant than spatial and orientational variations, but prediction of fault zone hydraulic properties is a crucial uncertainty in all these, and similar, modelling studies. One approach to improving the description of fault-related heterogeneities in reservoirs is to use seismic anisotropy, as pointed-out by **Owen *et al.***, who demonstrate its value in predicting fault aggregate alignments and cluster distribution. **Foley *et al.*** consider numerical fluid flow modelling techniques in faulted reservoirs, noting limitations in many modelling programs, and conclude that the Boundary-Fitted Co-ordinate Technique allows for more realistic fault geometries to be modelled. Reiterating previous conclusions, they emphasize the importance of information on fault zone characteristics to enable confident predictions of permeability distribution in faulted reservoirs. The curvature analysis of gridded surfaces, particularly those generated from 3D seismic data, offers a means of predicting fracture distribution according to **Stewart & Podolski.** They argue that the sum of the absolute values of principal curvature reflects the spatial variance in strain, and hence to fracture density, and that these data could form an inexpensively-derived surface attribute of horizons mapped on 3D seismic data. **Couples *et al.*** emphasize the importance of strain partitioning during flexural (bedding plane) slip folding. They note that most petroleum reservoirs are created by fracture networks related to flexural deformation and that fracture characteristics reflect structural position within the fold.

The final part of the volume is devoted to four case studies, where some of the previously discussed concepts are applied to a range of different structural settings. **Younes *et al.*** evaluate fracture development and its preservation in complexly faulted basement blocks in the Gulf of Suez, Egypt. Outcrop and sub-surface examples are discussed, the latter using high-resolution FMS and FMI image logs for fracture detection, and variations in fracture development noted as follows: (1) enhanced fracture density resulted from sheeting, faulting and dyke emplacement, and (2) reduced fracture density occurs as depth of erosion of basement blocks increases. **Lonergan *et al.*** note the presence of pervasive polygonal extensional fault networks in Tertiary mud-dominated slope and basin floor depositional systems in the North Sea. Based on the detailed analysis of 3D seismic data they conclude that these types of faults formed during sedimentation and early burial and may be important conduits for fluid migration, both compaction/dewatering and secondary petroleum migration.

Both 3D seismic data and a continuous, 120 m long oriented core have been used by **Aarland & Skjerven** to characterize a major normal fault in the Brage field (Northern North Sea), which highlights the heterogeneous nature of the fault zone and variations in fracture density. This may have implications for other rift-related fault blocks in the North Sea and elsewhere.

Finally, **Fossen & Hesthammer** present an integrated structural geological analysis of one of the Northern North Sea's most complexly deformed rotated fault blocks, which contains the giant Gullfaks oil field. Most of the shear deformation is thought to have occurred by strain-dependent grain reorganization in the poorly consolidated Jurassic sediments, which resulted in reduced porosity. Forward modelling studies and detailed evaluation of the field's various structurally defined subareas are fully described.

This volume arose from the meeting of the Petroleum Group of the Geological Society on 'Structural Geology in Reservoir Characterization' which was held in March 1995 at Imperial College, London. We thank all the contributors to the meeting for stimulating this volume, and the authors and referees who brought it to fruition.

Michael Coward, Sezgin Daltaban and Howard Johnson
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