Zeitschrift: Bulletin für angewandte Geologie

Herausgeber: Schweizerische Vereinigung der Petroleum-Geologen und –Ingenieure; Schweizerische Fachgruppe für Ingenieur-Geologie

Band: 13 (2008)

Heft: 2

Artikel: The structure, content and growth of fault zones within sedimentary sequences

Autor: Walsh, John / Childs, Conrad / Manzocchi, Tom

DOI: https://doi.org/10.5169/seals-226684

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Mehr erfahren

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. En savoir plus

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. Find out more

Download PDF: 26.01.2026

ETH-Bibliothek Zürich, E-Periodica, https://www.e-periodica.ch

The structure, content and growth of fault zones within sedimentary sequences

John Walsh[1], Conrad Childs[1] & Tom Manzocchi[1]

Existing models for the growth of fault zones associated with normal faulting of sedimentary sequences range from conceptual models for fault zone architecture, incorporating components such as fault core and damage zone, through to a variety of fault wear models that explain established quantitative correlations between fault displacement and fault rock thickness. Despite the importance of faults in a variety of application areas, no unified model for fault zone evolution has been developed which incorporates the broad range of fault-related features and processes.

Exploring links between the scaling of different fault zone components and fault displacement, a quantitative model for fault zone evolution has recently been developed which attempts to reconcile fault zone structure with the repetitive operation of a small number of processes, including fault segmentation and refraction, and asperity removal (Childs et al. 2009). This model relates fault zone components characterised by different amounts of shear strain (where strain is measured as the ratio of displacement to thickness) to stages in a kinematic model, in which low shear strain structures, such as fault relays, become fault-bound lenses and eventually fault rock with increasing strain. This model helps to reconcile the main characteristics of fault zones developed within a broad range of host rock sequences and at different deformation conditions, but still recognises the inherent complexities of natural fault zones. The model is also consistent with recent studies of high quality outcrops which illustrate how the combined effect of host rock rheology and prevailing deformation processes is capable of generating the full range of fault rock types, including those which have a major impact on hydrocarbon flow, such as shale/clay smears within poorly consolidated sediments (Fig. 1) through to shaley fault

Fig. 1: Normal fault with vertical displacement of ca. 60 cm contained within poorly lithified, medium bedded, sand-clay Miocene turbidites of the Taranaki Basin, New Zealand. A continuous clay smear connects the footwall and hanging wall sides of an offset clay unit. The clay smear varies in thickness partly arising from synthetic Riedel shears within the fault zone. Modified from Childs et al. (2007).

[1] Fault Analysis Group, UCD School of Geological Sciences, University College Dublin, Belfield, Dublin 4, Ireland

gouges within lithified sediments (Fig. 2; e.g. Childs et al. 1997, 2007). The incorporation of either shale smears or shaley gouge within fault zones contained in siliciclastic sequences, is now recognised as one of the principal means of forming some fault-bounded traps and can have a major impact on intra-reservoir flow. Existing empirical constraints demonstrate that fault rock permeabilities decrease with increasing clay fraction (Fig. 3a) and provide a means of predicting fault rock permeabilities in the subsurface. Typically the clay fraction in fault rock is assumed to be equivalent to the clay fraction of the sequence which has moved past a point on a fault (a value which is sometimes referred to as the Shale Gouge Ratio), and permeability is calculated by assuming a particular transformation between clay fraction and permeability, which can vary with various factors, such as burial depth and clay type.

Despite the inherent complexities of fault zones, new approaches have been developed which are capable of incorporating the effects of faults in both hydrocarbon exploration and production models (Childs et al. in press; Manzocchi et al. 2008a, b, c). Recently published studies show that these

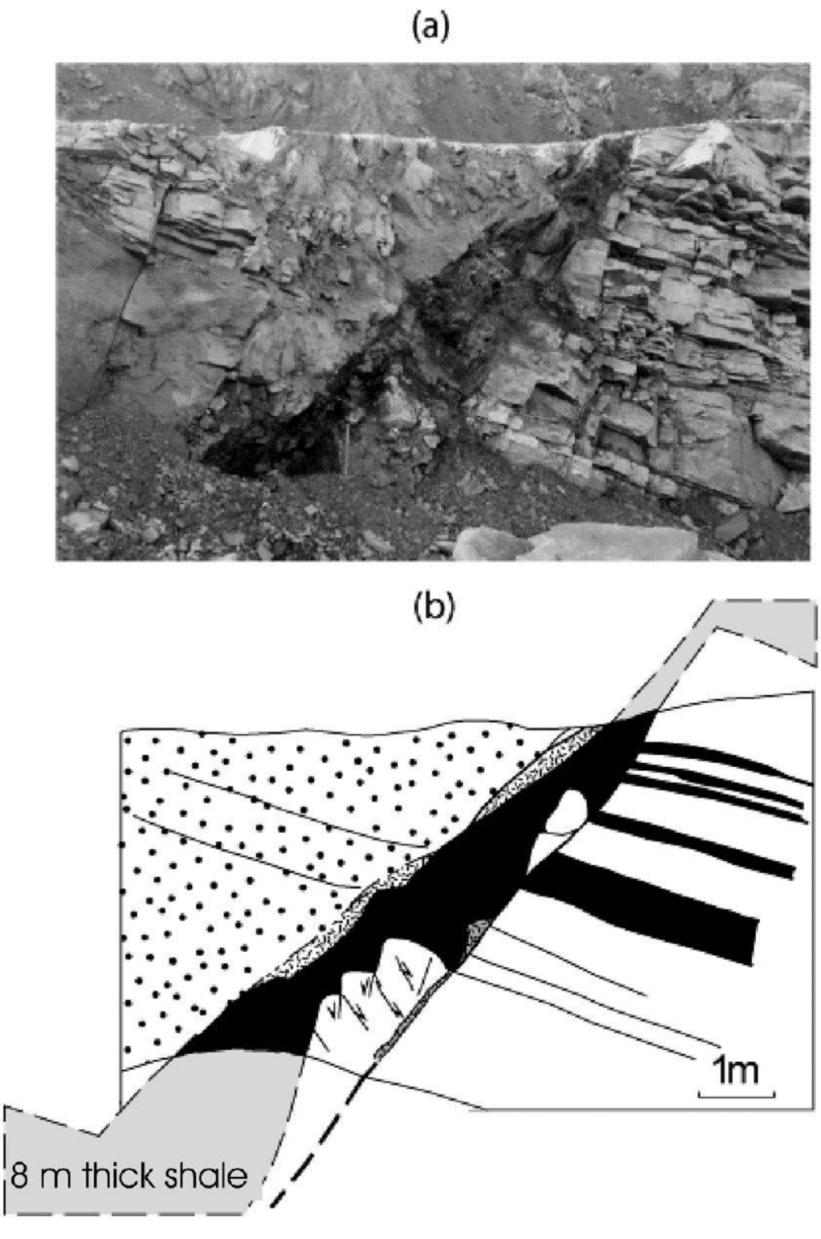

Fig. 2:
(a) Cross-section through a normal fault in a Carboniferous sandstone/shale sequence from a quarry in Lancashire, U.K. The fault dips to the left with a vertical displacement of ca. 15 m. (b) Sketch of the outcrop in (a). A well developed shale layer within the fault zone (black) is derived from an 8 m thick shale unit. The base of this shale unit is ca. 1 m above the top of the exposed face in the footwall and 1.5 m below ground level in the hangingwall. The fault separates sandstones in the hangingwall (stippled) from a mixed sandstone (no ornament) and shale (black) footwall sequence. Dense coarse stipple indicates sandstone and shale breccias. Modified from Childs et al. (1997).

methods provide an improved basis for modelling faults contained within reservoir production or hydrocarbon migration flow models of siliciclastic sequences, in which faults usually behave as barriers or baffles to flow. Some studies have highlighted interesting, though at first glance counter-intuitive, results (Manzocchi et al. 2008b, c). Fig. 3 shows, for example, that for a suite of synthetic Brent-type faulted reservoirs, produced by water injection along their flanks and crestal production wells, the effect of faults which are parallel to flooding directions is to decrease sweep efficiency and, consequently, recovery factors, whilst faults which are perpendicular to predominant flow directions can increase sweep efficiency, with consequent increases in recovery factors!

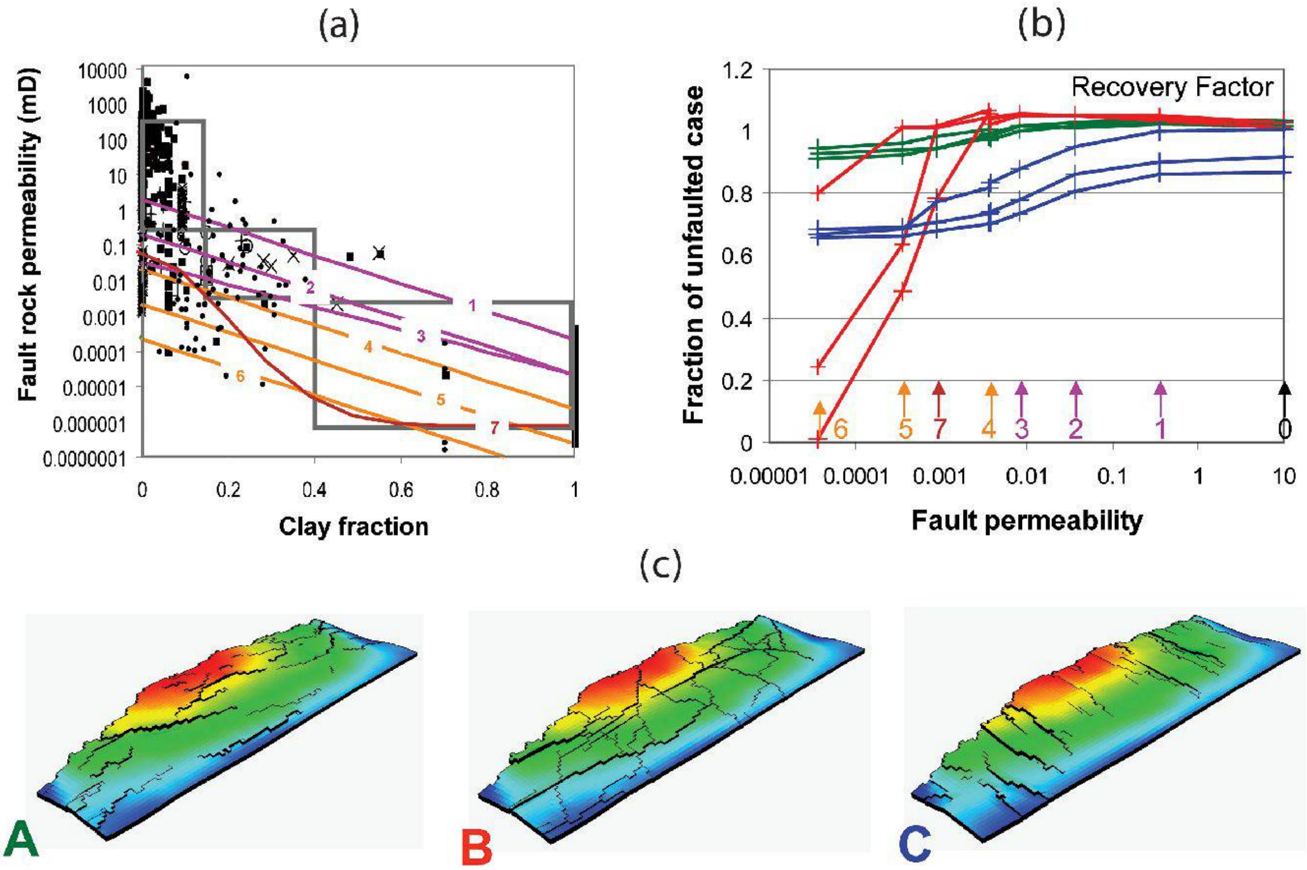

Fig. 3: (a) Plot of clay fraction vs. fault rock permeability for data from a variety of sources (see Manzocchi et al. 2008b). (b) Recovery factor vs. characteristic fault permeability for a suite of synthetic faulted shallow marine reservoirs (see Manzocchi et al. 2008b). Fault permeabilities relate to the numbered transformation curves shown in (a), and specifically the permeability of each transformation in (a) at a clay fraction of 0.2 (values on the right hand side are for juxtaposition, with no fault rock properties). Recovery factor is expressed relative to that of an unfaulted reservoir with the same sedimentology. Different coloured curves are for the three distinct fault patterns shown in (c), and the three curves for each pattern represent different strain (or displacement) levels. All of the reservoirs were produced from crestal producers with the injectors along the flank of the oil column. All wells were active from the onset of production and simple well controls were used in all cases – see Manzocchi et al. (2008a) for details. The curves in (b) show that the recovery factors are higher when faults are perpendicular to injector-producer pairs and drop dramatically when faults are parallel to injector-producer pairs, a feature which is attributed to the increase and decrease in sweep efficiency for faults which are perpendicular and parallel to flow respectively. Further information on these results is provided in a thematic set of Petroleum Geoscience (14/1); see Manzocchi et al. (2008a).

References

Childs, C., Manzocchi, T., Walsh, J.J., Bonson, C.G., Nicol, A. & Schöpfer, M.P.J. 2009: A geometric model of fault zone and fault rock thickness variations. Journal of Structural Geology 31, 117-127.

Childs, C., Sylta, Ø., Moriya, S., Morewood, N., Manzocchi, T., Walsh, J.J., Hermanssen, D. In press: Calibrating fault seal using a hydrocarbon migration model of the Oseberg Syd area, Viking Graben. Marine and Petroleum Geology.

Childs, C., Walsh, J.J., Watterson, J. 1997. Complexity in fault zone structure and implications for fault seal prediction. In: Hydrocarbon seals – Importance for exploration and production. (Eds. Møller-Pedersen, P. & Koestler, A.G.), Norwegian Petroleum Society (NPF), Special Publication 7, 61-72.

Childs, C., Walsh, J.J., Manzocchi, T., Strand, J., Nicol, A., Tomasso, M., Schöpfer, M.P.J. & Aplin, A. 2007: Definition of a fault permeability predictor from outcrop studies of a faulted turbidite sequence, Taranaki, New Zealand. In: Structurally Complex Reservoirs. (Edited by Jolley, S.J., Barr, D., Walsh, J.J. & Knipe, R.J.). Geological Society of London, Special Publication 292, 235-258.

Manzocchi, T., Carter, J.N., Skorstad, A., Fjellvoll, B., Stephen, K.D., Howell, J.A., Matthews, J.D., Walsh, J.J., Nepveu, M., Bos, C., Cole, J., Egberts, P., Flint, S., Hern, C., Holden, L., Hovland, H., Jackson, H., Kolbjørnsen, O., MacDonald, A., Nell, P.A.R., Onyeagoro, K., Strand, J., Syversveen, A.R., Tchistiakov, A., Yang, C., Yielding, G. & Zimmerman, R. 2008a: Sensitivity of the impact of geological uncertainty on production from faulted and unfaulted shallow marine oil reservoirs – objectives and methods. Petroleum Geoscience, 14, 3-15.

Manzocchi, T., Matthews, J.D., Strand, J. A., Carter, J.N., Skorstad., A., Howell, J., Stephen K.D. & Walsh J.J. 2008b: A study on the structural controls on oil recovery from shallow marine reservoirs. Petroleum Geoscience, 14, 55-70.

Manzocchi T., Heath A.E., Palananthakumar B., Childs C. & Walsh J.J. 2008c: Faults in conventional flow simulation models: a consideration of representational assumptions and geological uncertainties. Petroleum Geoscience, 14, 91-110.