Practical Considerations for Fault Seal Analyses: Insights from AI and Empirical Relations

John G. Solum, Shell

Geologically meaningful fault seal analyses require the identification of the location of cross-fault reservoir-reservoir juxtaposition windows and an estimation of their properties. Locating these windows is difficult in large part due to two factors: 1) fault interpretations are prone to errors, and lookback studies indicate that this has been the case for decades; 2) the expression of faults on 3D seismic is inherently ambiguous, resulting in uncertainty in the spatial positioning and extent of interpreted faults, and therefore in the location of juxtaposition windows.

The use of AI provides an opportunity to address these longstanding issues. The use of rigorously trained AI models helps ensure that fault inferences are geologically and geometrically consistent and provides a key input for a process to help quantify the ambiguity of the seismic expression of each fault. This results in a confidence ranking that is used to help define structural scenarios and to guide how faults are represented in flow simulations.

Estimation of the properties of juxtaposition windows is also prone to difficulties since the scale of architectural elements of fault zones that control cross-fault fluid flow is below the limit of seismic resolution. For example, the width and continuity of fault gouge exists at the meter scale, and therefore cannot be resolved on even the highest resolution 3D seismic datasets, implying that faults with different subseismic fault zone architectures and fault seal capacities will appear the same on seismic data.

The use of empirical relations helps overcome this obstacle to fault seal analysis. Compilations of SGR and across-fault pressure differences at weak points on cross-fault juxtaposition windows show significant scatter. For example, while greater SGR values can be associated with greater maximum pressure differences, there are usually weak points with low pressure differences for every value of SGR. In other words, the non-uniqueness between SGR and pressure difference provides meaningful information related to subseismic variations in fault zone architecture. It therefore provides a means to implicitly account for these variations, which are too small to explicitly measure on seismic data.

A combination of a workflow that uses AI to highlight faults on seismic data coupled with probabilistic estimates of fault seal derived from empirical relations helps to ensure that cross-fault juxtaposition windows are accurately identified, and that they are assigned a geologically realistic range of fault seal potentials.

Uncertainties in fault sealing calculations: what is it and how should we respond?

C. Hermansrud, Equinor

Forecasting fluid flow across faults is important for hydrocarbon exploration and production, safe storage of CO_2 in the subsurface and groundwater drainage. While such forecasting obviously comes with some uncertainty, surprisingly little work has been addressing the magnitudes ot these uncertainties. We have performed analyses of fault sealing accuracy assessments by back-calculating fault sealing capacity from exploration and production data. We then varied the most important parameters in such calculations to assess the impact of their uncertainty to the calculated fault-sealed column heights. The parameters we varied included seismic interpretation, quantification of clay in the fault planes, and probabilities for sand continuity from wells to faults.

The analyses included a detailed sealing analysis at the Njord Field offshore mid Norway. This analysis concluded that the impact of burial depth is here larger than previously thought, whereas the impact of clay content in the fault planes (in the 15-40% SGR range) has been overemphasized. This result emerged both from analyses of pre-production pore pressure and column height data across the field, and of analyses of fault multipliers from history matching from the same field. These results are consistent with published laboratory data. We argue that some previously noted relationships between in-situ observations of fault sealing and clay content may have other causes than a causal relationship between these two parameters in the investigated SGR range.

Analyses of the consequences of uncertainties inherent in seismic interpretation and clay content quantification were in some cases seen to be sufficiently large to completely change the main conclusion of fault sealing assessment. We suggest such uncertainties have to some extent been neglected because interpreted seismic lines and the bases for clay content calculations are rarely published.

Experiences of SGR/Fault Permeability curves

Signe Ottesen, Equinor

In this presentation SGR/fault permeability curves for 13 fields will be shown together with the data. One key takaway is that host rock permeability for the same SGR may vary a lot, and so does the fault permeability, so local calibration is key.

Simple cross-plots of data from the Equinor fault property database show that for individual fault rock types the reduction in fault permeability compared to undeformed rock have a better correlation than SGR/ fault permeability. The relationship to depth has also been investigated and reduction relate somewhat to depth, but order of magnitude reduction in fault permeability vs host rock permeability for clean rocks does vary by 1-2 orders of magnitude at the same depth for the different fields investigated (Figure 1).

The SGR/Fault permeability curves probably work to some degree since they are locally calibrated, but there are indications that we are not including all processes, and lately the old methods are rightfully being questioned. Cloud based solutions may allow for multivariate analysis and Machine Learning, and new dependencies may be statistically found. New relationships should be welcome, and hopefully the new relationships can also be linked to physical processes. These data show that it is difficult to see the logic in calibrating general fault seal algorithms against single parameters like depth or SGR as the database demonstrate that host rock and fault rock permeability for the same SGR may vary a lot, and that the correlation of reduction in permeability to depth is only a weak correlation.

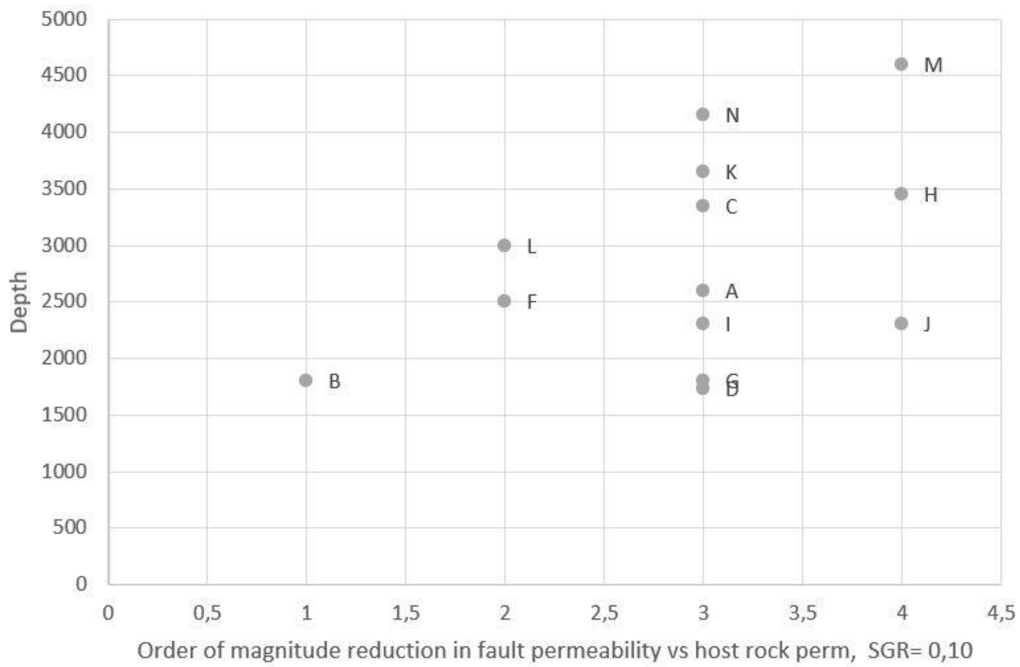

Figure 1 *Relationship between order of magnitude reduction in fault permeability vs host rock perm for clean rocks with SGR=0.10 for 13 fields (A,B,C,D..) on the* Norwegian Continental Shelf.

Integrating Overpressure Data to Refine Fault Permeability Predictions: Lessons from the Njord Field

P. Muller, Equinor

Fault permeability prediction is crucial for understanding reservoir compartmentalisation. Traditional methods rely on empirical relationships between permeability, clay content, and burial depth, often calibrated with core data or subsurface observations of fluid pressure and hydrocarbon contact offsets across faults. However, discrepancies exist between core data, which suggest no significant relationship between host rock clay content and fault permeability for phyllosilicate-framework fault rocks when all available data points are lumped together (e.g. individual formations and burial depth), and subsurface calibration data, which imply otherwise.

As Darcy's Law and Ohm's Law are equal, fault rock permeabilities can be calibrated via pre-production overpressure data at field-scale by applying an analogy from electrical engineering. This approach is based on an input (highest overpressure, fluids entering the field) and an output (lowest overpressure, fluids leaving the field) overpressure and optimising a permeability equation to fit the observed overpressures within the field. We applied this approach in the Jurassic reservoir section of the Njord field, where faults span depths of 2.7-4.5 km and have clay contents from 8.9 to 25.7%. We included depth and clay content in the fault permeability equation.

Our findings indicate that for the phyllosilicate-framework fault rocks in the Njord Field, fault rock permeability decreases with burial depth, while clay content has minimal impact. Sensitivity analyses confirm the robustness of these results. Consequently, solely SGR-based fault permeability equations may not accurately predict fault permeability for seismic-scale faults at Njord. These insights are critical for understanding structurally controlled reservoir compartmentalization in fields with a similar geological setting as Njord.

Estimating fault zone permeability from petrophysical data and history matching in the Ærfugl field, Norwegian Sea

H. Anderson, A. Stav, J. Ciccarelli, A. Hjellbakk & D. Mirza, **Aker BP**

A horizontal production well in the Ærfugl Field, Norwegian sea, encountered a normal fault with meter scale offset. Whilst this fault was predicted with low confidence pre-drill on seismic reflection data, it was confirmed by petrophysical data including deep-reading resistivity and logging while drilling (LWD) azimuthal density images (ALD). Throw is estimated from the resistivity data between 7 m and 15 m, with the well passing from the hanging wall into the footwall with increasing measured depth. Interpretation of dips from the ALD image indicate low bedding dips to the west, consistent with the seismic interpretation. A minor fault, with sub-metre scale offset on deep-reading resistivity is encountered at 3540 m MD. The major fault zone is encountered at 3640 m MD and is comprised of 4 individual fault surfaces. These faults dip at ca. 60 degrees to the SW and are associated with increasing bedding dip and changes in dip azimuth. The dip corrected thickness of the fault zone ranges between 5 m and 10 m depending on whether the zone is measured as comprising just the mapped slip surfaces or the surrounding high-density features respect. This gives a thickness to throw ratio of 1:1.3 which is broadly consistent with published fault zone thickness databases.

LWD pressures indicated there was a ca. 0.5 bar pressure difference across the wider fault zone at the time of drilling, indicating a baffle during depletion. Moreover, subsequent crossflow observations during well shut-in Pressure Transient Analysis are evidence of large differential pressure along the wellbore that have developed further due to production. History matching using the full field simulation model, where the fault is modelled as single surface, suggests the fault transmissibility multiplier in the range of 0.01 and 0.05. Using Manzocchi et al, 1999's definition of a fault transmissibility multiplier, it is therefore possible to back calculate fault zone permeability. This indicates that fault zone permeability is 3-4 orders of magnitude lower than the average permeability of the hanging and footwall reservoir. This is broadly within the range of a global database of fault permeability vs wall rock permeability measurements, but significantly lower than the P50 correlation.

This workflow presents an alternative way to predict fault zone permeability and, therefore, fault transmissibility multipliers. One that does not rely on calibration of fault seal algorithms with either local or global fault rock permeability databases.

Fracture connectivity & permeability by using high-resolution borehole image logs

Attila Petrik[1], Carsten Vahle[1], Ingrid Piene Gianotten[2], Liv Inger Trøan[2], Luis Rojo[2], Kevin Galbraith[2]

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Fractures are fundamental brittle structures playing a key role in exploration of mineral resources, transportation of geofluids, reservoir compartmentalisation and storage of CO_2, H_2 or nuclear waste deposits. Besides geometrical attributes (e.g. orientation, frequency, spacing), the spatial arrangement of a fracture network is equally important and determines the rock physical properties (Fig. 1). This study focuses on the quantitative characterisation of fracture network connectivity by using high resolution ultrasonic and electrical borehole images on a test well 16/1-34 A (Utsira High, North Sea), which penetrated Permian Zechstein carbonates and granitic basement. Furthermore, fracture topological parameters are used to refine and improve the analytical solution of effective fracture permeability calculation of separated fracture zones.

Fifteen fracture zones were distinguished based on the orientation of fracture sets and fracture intensity. Zone 2 & 3 in carbonates have well-connected NNE and NNW-dipping chemically assisted open fractures with the largest apertures (20–40 mm) and fracture porosities of ~2%, which result in extremely high fracture permeability. The fracture orientation is more complex and the fracture frequency increases to 12-20/m in stiffer basement from fracture Zone 8 downwards. All topological parameters indicate an excellent connectivity in the basement, being highest in Zones 9 and 10. The average fracture-bounded block size is < 0.01 m^2 and the block intensity is nearly zero, implying a heavily disintegrated basement rock. In contrast, the sparsely distributed fractures between 2118 and 2148 m and below 2184 m are related to lower rock stiffness. Effective fracture permeability varies throughout the basement fracture zones and is strongly influenced by the aperture, length, fracture transmissivity and connecting node frequency.

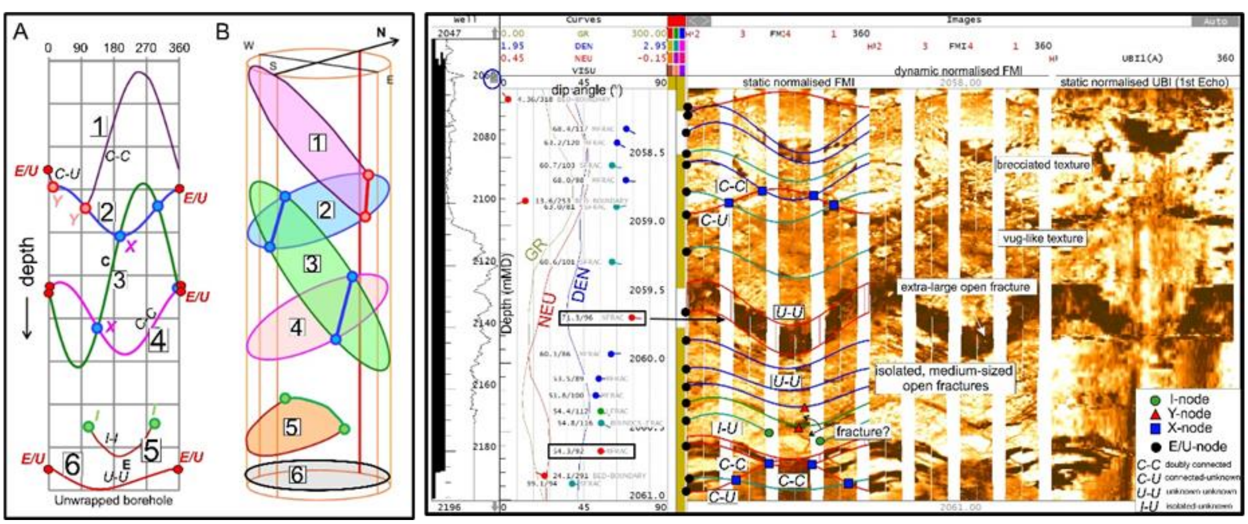


Fig. 1: A) Fracture sinusoids revealing different node and branch types in an unwrapped borehole (mod. Sanderson & Nixon 2015). (B) 3D geometry of the corresponding fractures in a borehole. The numbers indicate the same fractures. (C) Fracture nodes and branches in electrical (FMI) and ultra-sonic (UBI) image logs. Dark fractures are likely open and their apertures can be measured directly in the image (e.g. XFRAC at 2059.7 m).

Low Acoustic Impedance within Fault Zones of the Wisting Field: Gas leakage or fault damage zone?

J. H. Butcher, N. Cardozo, L. Schulte, L. Rojo, UiS

The Wisting Field was discovered 300 km north of Hammerfest and is a heavily faulted Triassic – Jurassic oil-bearing reservoir. It lies between the Maud Basin and the Hoop Fault Complex (HFC) which is a NE – SW fault system exhibiting typical graben geometry. The Wisting field, however, exhibits orthorhombic faults with numerous orthogonal intersections dominating orientations of WNW – ESE and NNE – SSW trends which have divided the reservoir into 3 main blocks (WC, WCW, and WCS, Fig. 1a). The area has also been subject to ca. 1500 m of uplift and erosion.

Observations of these orthogonal fault zones in Wisting has revealed a distinct reduction of acoustic impedance (A_{imp}) within select fault zones originating at the reservoir interval (Fig. 1b & c). In this study, the low A_{imp} has been modelled in five faults (F1 – 5, Fig. 1a). Differences in the models were observed between the orientations; fault zones that were orientated WNW - ESE (Fig. 1b – c) when compared to fault zones orientated towards NNE – SSW (Fig. 1d). Two agents have been proposed to explain this phenomenon: 1) gas saturating the fault zones via up-dip leakage is facilitating reduction in acoustic impedance caused by exsolution and gas decompression due to uplift and erosion; 2) fault damage zone has affected the elasticity of the fault rock, causing a reduction in acoustic impedance.

Results suggest that low acoustic impedance dominates the WNW – ESE fault zones (Fig. 1b – c) while being sparse in NNE – SSW faults (Fig. 1c). Two theoretical explanations are presented: 1) gas is more prevalent within WNW – ESE fault zones; and 2) WNW – ESE faults exhibit higher damage zone magnitudes when compared to NNE – SSW fault zones. Both hypotheses suggest a complex stress and strain evolution enacted on the faults that is undoubtedly due to orthorhombic fault progression and embrittlement due to loss of vertical load between the Mesozoic – Cenozoic.

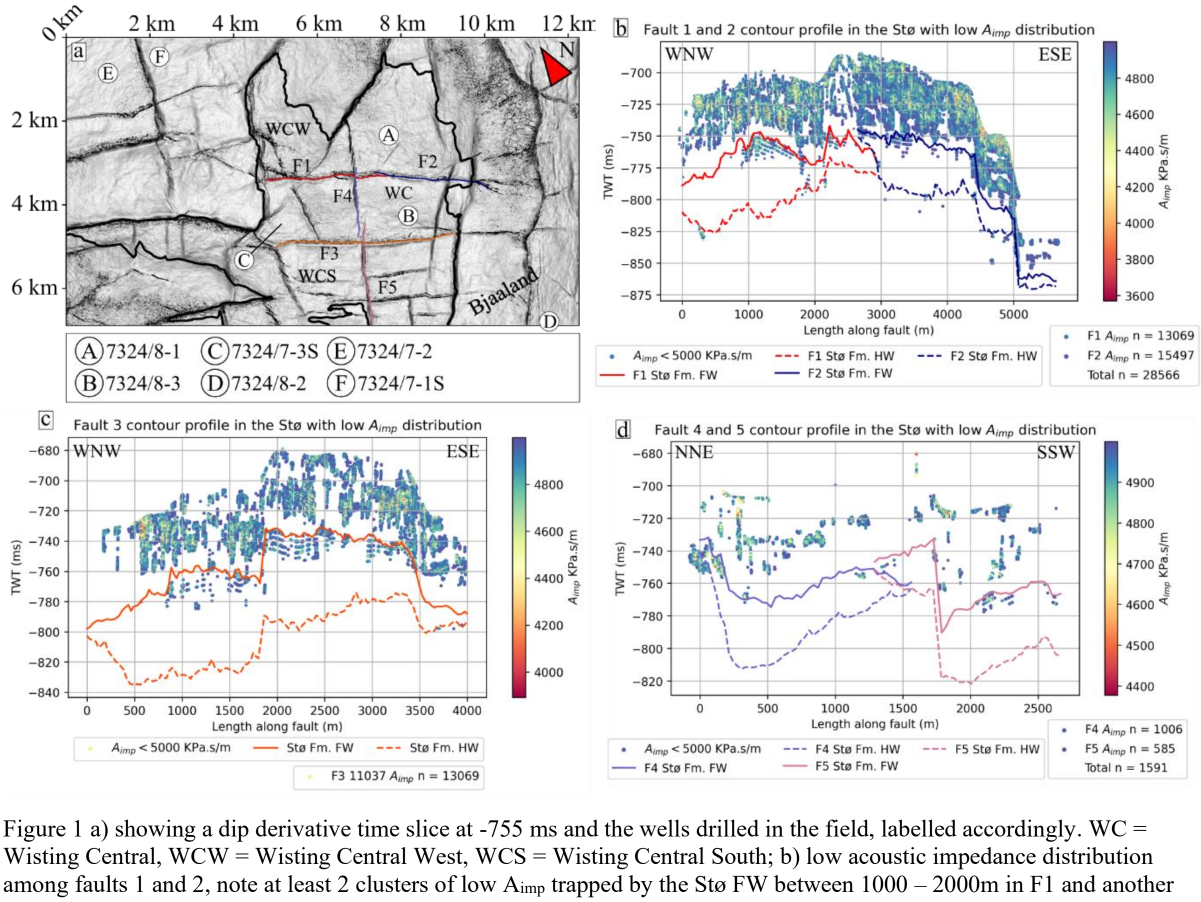


Figure 1 a) showing a dip derivative time slice at -755 ms and the wells drilled in the field, labelled accordingly. WC = Wisting Central, WCW = Wisting Central West, WCS = Wisting Central South; b) low acoustic impedance distribution among faults 1 and 2, note at least 2 clusters of low A_{imp} trapped by the Stø FW between 1000 – 2000m in F1 and another between 2000 – 3500m in F2; c) low acoustic impedance distribution of fault 3, note numerous clusters of low A_{imp} in the WNW and ESE sections of F3 spanning between 750 – 3500m; and d) low acoustic impedance distribution for faults 4 and 5. Contours are representative of the Stø Fm footwalls (FW) and hanging walls (HW). Note how the densest clusters exist above the Stø Fm, meaning they saturate fractures within the top seal Fms.

Integrated structural interpretation of the Valhall Field, Norwegian North Sea

L. Frette, E. Serigstad, H. Anderson, Aker BP

The reservoir structure at Valhall is challenging to image on seismic because of significant amounts of hydrocarbons/gas in the overburden. To better understand how faults and fractures affect reservoir deposition, fluid flow, and production performance, it is essential to use an integrated structural interpretation approach. By combining consistent structural interpretation from seismic data with well log data, 4D seismic signal development, and insights from structural field courses, some of these questions may be resolved.

The Valhall field was discovered and developed using 2D seismic and has, since 1990, been covered by numerous 3D surveys, as well as reshoots of these for seismic surveillance (4D seismic). The Life of Field Seismic (LoFS) array was installed in 2003, covering ~70 % of the field, and has been used for 4D monitoring. The reliability of the array has declined with time, and the more recent LoFS-surveys have been acquired using nodes covering a larger area. New processing methods and technologies, including Full Waveform Inversion (FWI) and Converted Wave (PS) processing and imaging, have also been explored extensively, resulting in notable enhancements to imaging over time. However, considerable challenges remain.

The results from a comprehensive re-processing of Ocean Bottom Seismic (OBS) data from Valhall, including advanced velocity model building with FWI and Q compensation have improved the confidence in fault interpretations near the crest of the structure due to better image quality within the seismically obscured area (SOA). The data now serve as the preferred dataset to anchor the interpretation to when integrating it with other data sets.

The revised structural interpretation shows that the fault orientations change across the field, from near N-S (curving NE towards the Mode Salt Diapir) in the North, to a more NW-SE direction at the crest of the structure, and back to NNE-SSW in the South, potentially connected to a relay zone in the Skrubbe Fault Zone and salt movement towards Mode area and Hod West. Relay zones are also seen locally across the structure at a variety of scales, and 4D seismic hardening indicates evidence of fluid movement along structures related to these relay zones.

The combination of the newly re-processed seismic data and integrated interpretation of deeper structures and overburden faults and how they link with the reservoir structures together create an interpretation that will allow improved reservoir characterization, infill well target identification and well planning.

Structural derisking for CO_2 storage

Presenter: Elin Skurtveit, NGI - with input from NCCS research team

To qualify a reservoir for CO_2 injection the containment risk needs to be assessed. Key challenges relate to demonstrating the sealing capacity for faults in saline aquifers, estimate safe injection pressure and to mitigate fault reactivation and fluid migration out of storage complex. The current work has focused on improving the workflow for how we characterize faults and model fault permeability and reactivation. New characterization and interpretation methods focus on quantifying range and uncertainties in fault geometries and properties. Modelling approaches includes failure probabilities and fault flow models for the overburden.

The work demonstrates uncertainties in fault geometry related to interpretation strategies, whereas a detailed evaluation of effect of uncertainty in fault geometries related to the depth conversion method used for the seismic show limited effects on seal capacity and integrity analysis. A sensitivity study of the influence of different parameter used in fault failure risk assessment show a distinct shift in the most influential parameters depending on depth: fault strength parameters are more crucial at shallower depths, while stress parameters become significant at deeper depths. Our results provide input to existing fault analysing workflows and highlights a specific need for more data for sealing formations and the overburden. There is currently a lack of calibration data from the CO_2 injection licenses, and comparison and calibration of models using suitable O&G projects could be a way forward to demonstrate the value of the new models.

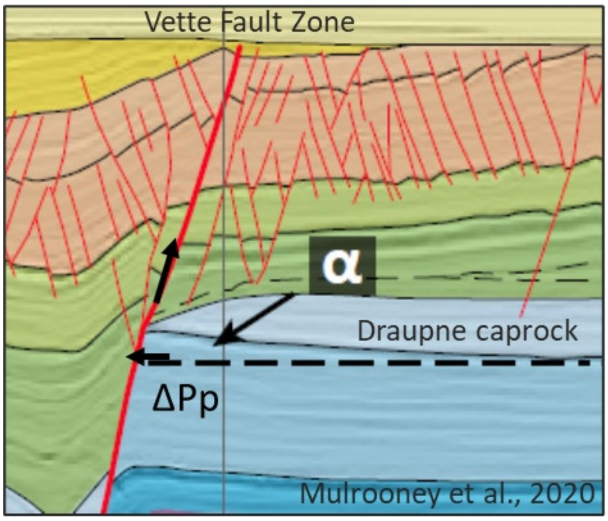


Figure identifying along fault fluid migration up into overburden as a risk related to CO2 storage in fault bounded aquifers (modified from Mulrooney et al 2020).

Acknowledgment

The work has been carried out in a collaboration between NGI and UiO as part of the structural derisking task in NCCS (257579/E20) and the related FRISK project (294719)

Basin analysis/pore pressure analysis to define compartmentalization

Stephen O'Connor

Global GeoPressure Advice

The term "seal" is applied both to petroleum movement in the subsurface as well as to restriction on the flow of water in basin aquifers.

Typically, we consider a seal as a rock preventing natural buoyancy-related upward migration of hydrocarbons or, to extend this, any rock capable of preventing all pore fluid movement (oil, gas and water) over substantial periods of geologic time. This, however, ignores the fact that seals can be effective over production rather than geologic timescales. Local restriction of flow may be enhanced by 2-phase fluids (water and petroleum or non-hydrocarbon gases).

The present understanding of permeability of fine-grained rocks which act as effective baffles over geological time to fluid flow is that they have values in the nanoDarcy range.

Seals, which can of course be vertical or lateral, can be due to low fault plane permeabilities, diagenetic sealing or deposition via shale-out.

FTWD ("Formation Testing While Drilling") and WFT "(Wireline Formation Tests E.g. Repeat Formation Tester) provide a highly accurate measurement of formation (pore) pressure (and fluids present) and as such are invaluable to determine water phase pressure (or more correctly, "overpressure" and any interval reservoir barriers. These tools are less reliable at elevated temperatures.

Wireline petrophysical logs such as gamma ray can be used to discriminate low permeability intervals that could act as barriers to communication. In the absence of these data, it may be possible to identify impedance contracts within a reservoir that could be interpreted as barriers, if seismic resolution allows.

Laboratory tests such as uniaxial and tri-axial tests can be used to determine physical properties of seals, parameters such as Poisson's Ratio and Young's Modulus. Seal permeabilities can be determined using MCIP techniques, but as in all tests of this nature, reservoir conditions must be simulated.

Seals can be breached in various ways, including membrane and mechanical failure (the latter due to potentially "zero" effective stress) and geomechanical re-activation of faults amongst others.

Pore pressure, and changes thereof, are implicit in much of the above, but not always. For example, the evidence is that an overpressure reservoir in the water-phase is not more prone to membrane failure than a normally (or hydrostatically) pressured reservoir.

There are repeated laboratory experiments on core plugs that suggest that it is the water pressure that controls breach rather than hydrocarbon buoyancy.

There is evidence that traps do not breach (mechanically) at "zero" effective stress, but rather, "before".

If we use the typical column height equation, of seal capacity (as defined by minimum stress, Leak-Off), pore pressure) and water, hydrocarbon density differences, hardly any of the (top) seals in the North Sea should have an issue with hydraulic failure, using data at the present time.

The use of a "regional" failure line is fundamentally wrong.

What effect does ice loading have?

This talk will focus on pore pressure and its influence on compartmentalisation.

Unraveling fault geometry and properties

A. Torabi, UiO

Faults are complex structures that introduce heterogeneities and anisotropies to their host rock. Therefore, studying fault geometry, architecture, and properties (petrophysical and mechanical properties) are important for different applications including hydrogen and CO_2 storage underground, geothermal energy management, petroleum exploration and production, earthquake seismology and geological hazard studies among others.

Faults can be studied at different scales and through different methods. As each method has its own limitation and constraint, fault data are usually biased and influenced by the method. Currently there are less data available from fault properties in comparison to the fault geometry. In addition, there are limitations to the algorithms used for analyzing fault seal integrity. While, details of fault core and damage zone could be investigated through outcrop studies, seismic data can provide a better overview of 3D structure of the fault, which is not usually accessible through outcrops. Recent advances in the application of seismic attributes and deep learning on both seismic and well data have made it possible to go beyond the seismic resolution and extract not only the fault geometry but also the properties (e.g. Figure 1).

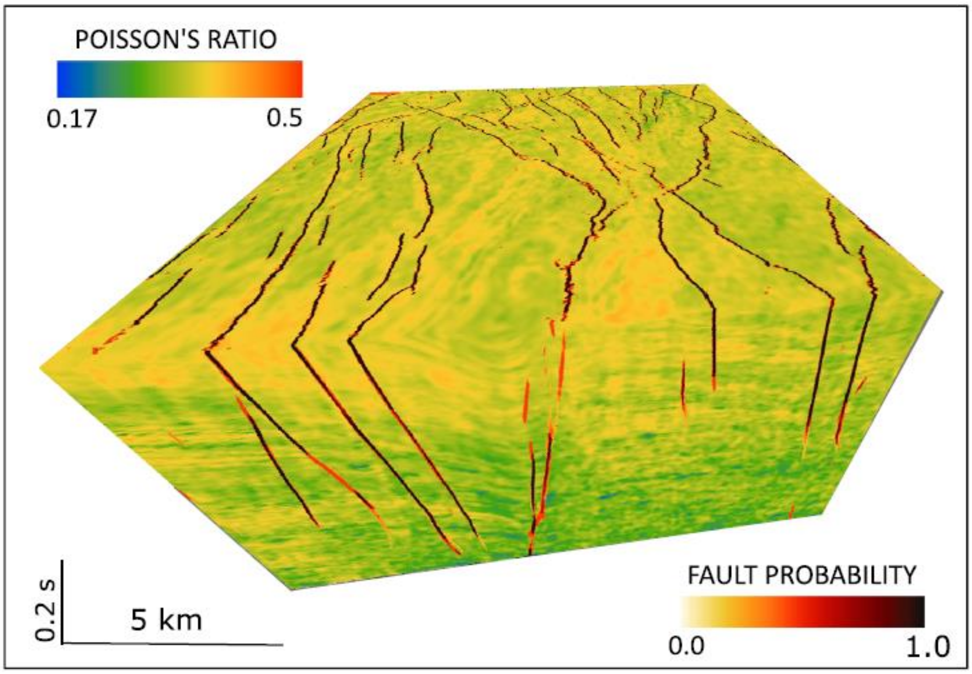


Figure 1: Fault trace probability and property (Poisson's ratio) prediction in 3D using deep learning. After Torabi et al., 2023 (in Earth Science Reviews).

Ivar Aasen AI fault interpretation gives new insights

Akram Ourir, Sval Energi

Ivar Aasen is an oil field located on the Utsira High in the North Sea. The reservoir has multiple zones and numerous faults forming drainage segments with varying connectivity. Integrating fault interpretations, 4D data and production data is crucial in Ivar Aasen to identify infill targets and optimize field drainage.

Manual seismic fault interpretation can be a very intensive, bias prone and time-consuming process especially in this complex structural setting. While geoscientist inputs & knowledge are crucial, AI fault network methods can provide quick alternative interpretations and highlight features that could be missed by the seismic interpreter.

As a non-operating partner in the license, Sval utilized AI fault interpretation functionality to generate alternative fault interpretations of the Ivar Aasen structure. The aim was to support the partnership's subsurface evaluations of targets for upcoming infill drilling campaigns by presenting structural interpretation updates and alternatives to complement 4D seismic and production datasets.

Five AI fault network realizations were generated using different neural networks within Geoteric software on good quality seismic data. The results were then imported to Petrel for visualization and generation of multiple surface attributes. While the AI faults dips and inter-connections require geoscience expert input for finetuning the results, the AI network method revealed important information about the reservoir segmentation and complexity.

The AI faults were used in an integrated static and dynamic analysis to assess communication pathways between injectors and producers in evaluations of infill drilling targets. Integrating AI fault models with 4D seismic and PLTs was useful for understanding reservoir drainage, for example in the west area a fault compartment was confirmed using the AI fault network method and proven by pressure data from a recent infill well.

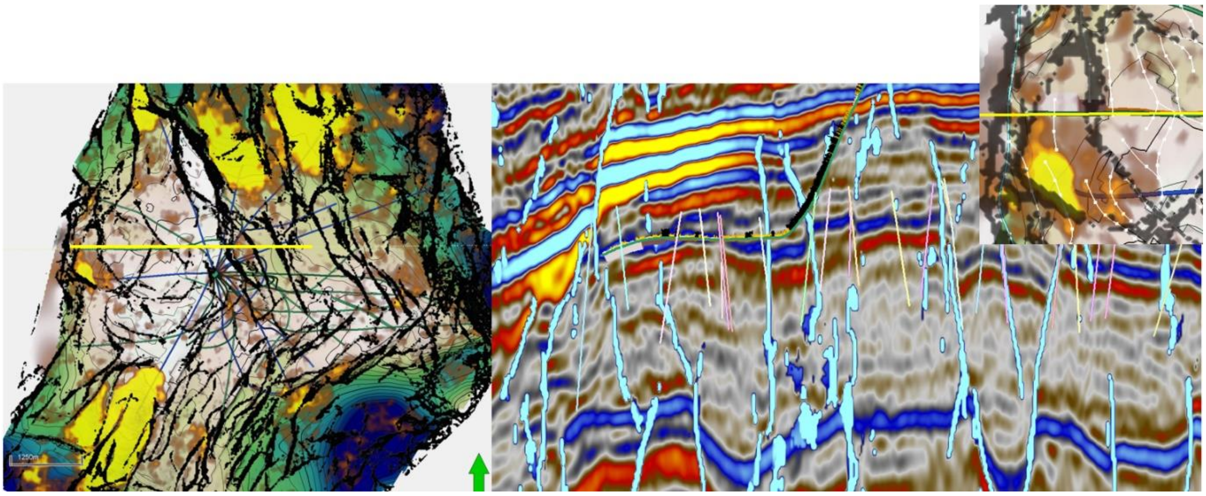


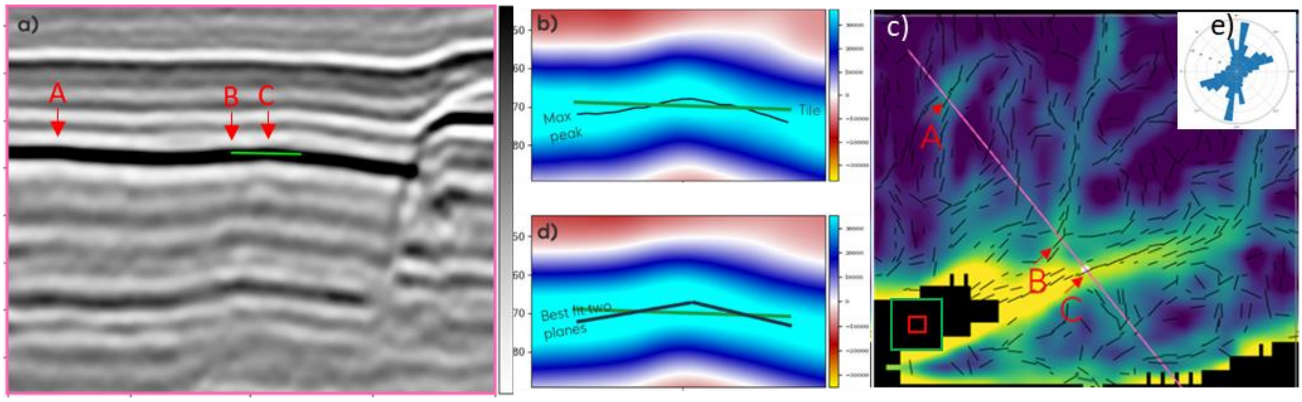
Figure: Geoteric AI fault picking inline with well observations of compartmentalization and 4D pressure effect,

Detecting Subtle faults using Seismic Tiles.

Øyvind M Skjæveland, Equinor and Carl-Inge Colombo Nilsen, Norwegian Computing Center (NR)

The basic principle in the Seismic Tiles concept is that all reflector segments are detected and represented by tiles, where a tile is a planar, rectangular surface with a typical size of 250 by 250 meter, or about 21 by 21 IL by XL. Here, the term "planar" means to have zero curvature, but any dip and azimuth. See www.seistiles.com for material describing the Seismic Tiles data structure. A ceramic tile is a good analogue to a seismic tile. Similar to ceramic tiles, seismic tiles are laid out on a grid and their vertical position, dip and azimuth adapt to the underlaying surface / the seismic reflector. A seismic tile is the best planar representation of a seismic reflector in the very local area where the tile sits. If the seismic reflector itself is planar over this area, (i.e., the underlaying geological stratum is locally planar) the tile will represent the reflector well. If there is a subtle fault in this location, however, the planar tile is not able to adapt fully to the reflector, as the seismic reflector will not be planar when affected by the fault.

By letting the tile adapt to the seismic in a very specific way, we are able to model subtle faults but not fit to noise. We do this by cutting the tile in two pieces using a straight line cut, keeping the constraint that each of the two tile pieces should be planar. (The analogy of a ceramic floor tile work well – cutting a tile in two allows it to fit better to a non-planar surface). The two tile pieces are independent – they can have different dips and an arbitrary vertical separation. We try all possible cuts, (all azimuths and not only through the center) and for each cut we fit the two pieces to the seismic and measure how good the fit is.



The figure above from Snøhvit shows *a)* a line with one single tile in green. Note that, because of a subtle fault in this location, the planar tile does not fit perfectly to the reflector. This is further illustrated in *b)* which is a zoom-up of the section at the tile location. *d)* shows that if the tile is broken in two, the fit to the seismic is better. The map in *c)* shows the result after repeating this process for all tiles in all locations along the strong reflector at this level. The color in the map shows how much better the fit is after breaking the tile in two along a straight line and is thus a proxy for fault magnitude. Each lineament on the map represents the best way to cut a single tile and is calculated independently. If an extensive subtle fault is present in the data, the lineaments will line up. The green rectangle in the lower left of the map shows the size of the tile, i.e. the area that goes into the calculation, whereas the red rectangle shows the display size of the tile, dictating the size of the individual lineaments on the map. The red rectangle is smaller as tiles are calculated with overlap. Since all information about these faults (azimuth, throw, magnitude, …) are available as tabular data it is easy to do analytics on them like displaying a Rose plot of the azimuth distribution of the lineaments on the map, shown in e).

As this is a fully deterministic algorithm, there is no need for training or labels. The tile calculation process is robust for noise, and thus this principle is well suited for identifying subtle faults in data with lower signal-to-noise ratio. The method has been applied also on such data, to be shown in the presentation along with a comparison to an ML approach (Thin Fault Likelihood). The approach using Seismic Tiles allows any analytics on subtle faults, combination with other attributes and logic such as the automated joint interpretation of horizons and faults presented at the Force 2023 meeting (available on www.seistiles.com).

STRUCTURAL GEOMODELING AND AI. A PRACTITIONER POINT OF VIEW

P. Kraemer , Wintershall Dea

Structural Geomodeling is being reshaped by the advent of AI (artificial intelligence). This paper aims to share my experience at building AI supported Structural Geomodels.
Seismic fault interpretation has traditionally been a time-consuming process. Twenty years ago, interpreters building detailed 3D structural geomodels spend 40 -70% of project time interpreting faults *(1).* However, the development of automated fault interpretation tools based on artificial intelligence (AI) and Machine Learning (ML), has shown promising results in reducing interpretation time. For instance, some studies have claimed up to a 95% reduction in interpretation time with the use of AI *(2).* AI- ML today, is having a significative impact in Structural Geomodelling.
Some of the questions nowadays are: -1 Which tools give best results in terms of Efficacity & Efficiency? -2 How much value is added to our workflows?

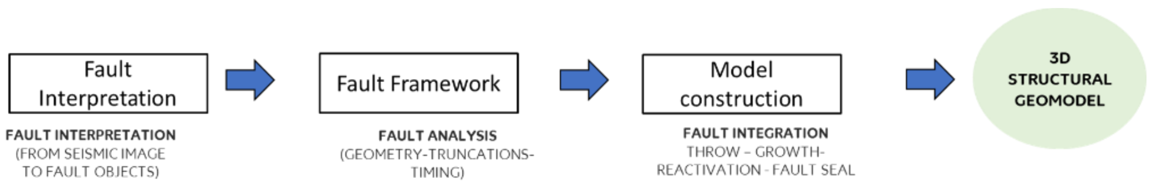


Figure 1. Structural Geomodeling Workflow discussed.

To answer the first question, we did during year 2023 a test of 8 different software's and three methods in a project named (AFIT) *(3)* The main outcome was that Efficacity and Efficiency significatively increase with the use of 3DCNN methods.
To answer the second question regarding how much value AI adds, a complete Structural Geomodelling Workflow was executed twice, first without the aid of AI tools and second with the aid of AI tools in fault interpretation, keeping all the other factors equal, including the interpreter. The result showed an increase in efficiency of >50%. Another improvement is the availability of several fault sets calculated from different surveys/reprocessing's/AI methods, providing "fault corridors" instead of a single fault reflecting the uncertainty in fault positioning.
Time saved in fault interpretation could be used in other specialized tasks such as *fault analysis* (geometry - truncations- timing) and *fault integration* to stratigraphy (throw analysis – growth faulting – reactivation – fault seal evaluation) which are still not fully automated.
The advent of AI-ML methods is reshaping the role of Structural Geologists. It could be either a high-level advisor to seismic interpreters, geomodelers, reservoir engineers etc., or alternatively be the "hands on" Structural Geomodeller that drive the whole model construction. The results presented here were achieved in the latest role.

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