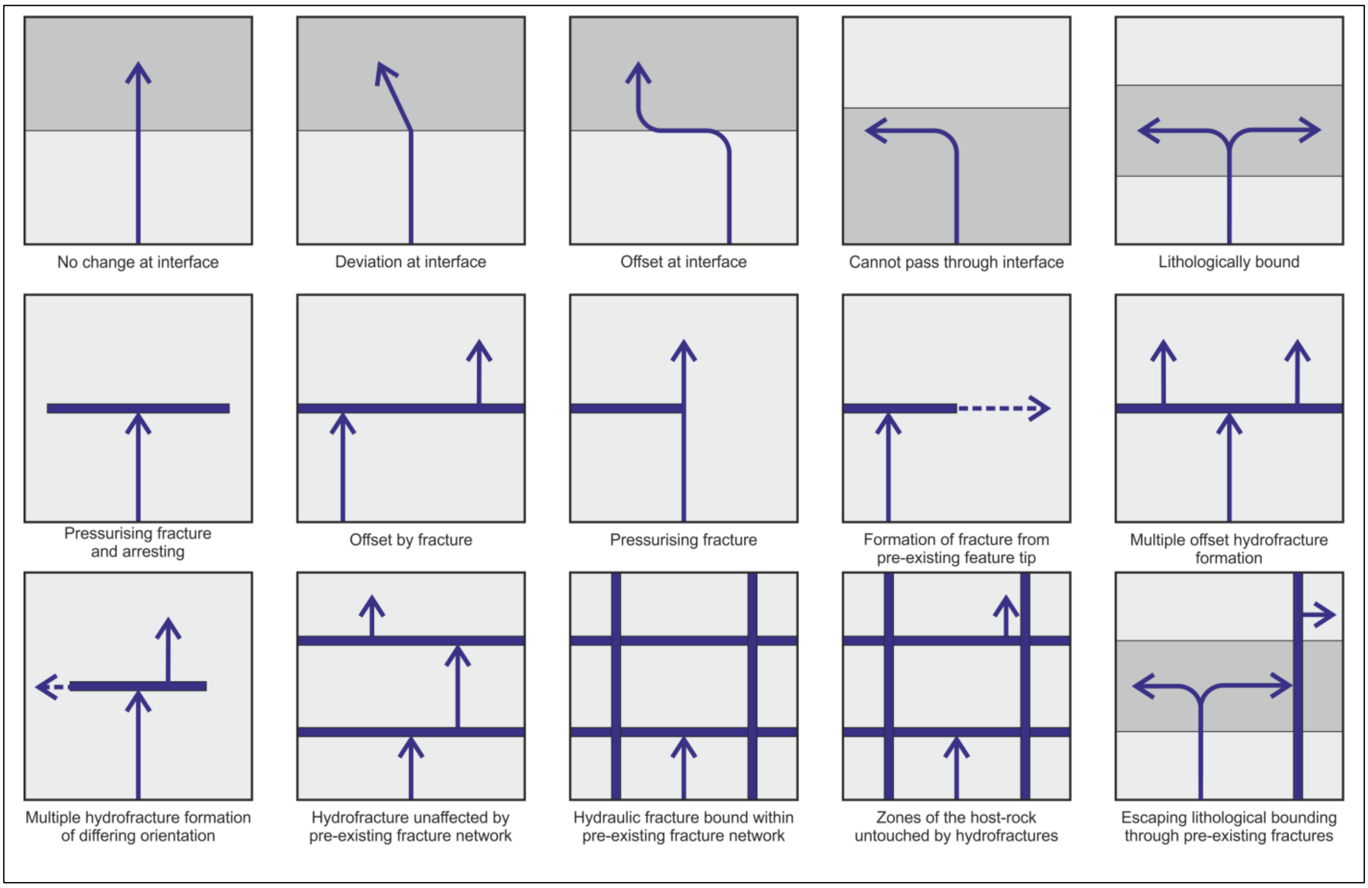
# RECOMMENDATIONS ON HYDRAULIC FRACTURING

R.J. CUSS, A.C. WISEALL, E.HOUGH




## Background

The use of hydraulic fracturing during shale gas recovery is a controversial topic. A simple question that is often posed is "where do the fractures go?" Classical fracture mechanics would state that fractures will grow in the direction of the maximum stress direction, which is normally in the vertical direction. However, the use of microseismic monitoring during hydraulic stimulation has shown a considerable lateral extent to the formed fractures and the vertical extent of the fractures is not as large as theory would suggest. Therefore, it has been suggested that hydraulic fracture migration is limited by a number of processes, including complex geological layering, changing material properties, the presence of higher permeability layers, the presence of natural fractures, the formation of hydraulic fracture networks, and the effects of fluid leak-off. This project aimed to investigate the controls on hydraulic fracture formation and growth.

## Study

A series of 62 experiments were conducted to answer three fundamental questions; how do hydraulic fractures initiate and propagate? How do hydraulic fractures interact with bedding and pre-existing fractures? Can hydraulic fractures become lithologically bound? Experiments were undertaken using a combination of analogue testing (synthetic clay samples) and on intact shale. The growth of fractures was directly observed using the Fracture Visualization Rig (FVR), with water injected into a pre-formed clay sample held rigidly by a glass and steel apparatus. High-speed video recorded the rapid propagation of hydrofractures in six geometries (single clay, simple layer, concentric layering, pre-existing fractures, square fractures and complex fractures). Samples were formed of ball-milled Bowland Shale and/or kaolinite with quartz filled slots representing fractures. Results were compared against cubic samples of clay tested within a Direct Shear Rig (DSR) and cylindrical samples of intact Bowland Shale.

## Results

The figure above summarizes the observations of the experimental program. Dependent on the physical properties of two adjacent clay-rich layers fractures either have no change of direction, deviate, offset or cannot pass through layer interfaces. Hydraulic fractures can therefore become litholigcally bound. Pre-existing fractures become pressurized as hydraulic fractures reach them, this can lead to offset fracture growth, formation of multiple new hydraulic fractures, and formation of new fractures in different directions to the original propagating fracture. In complex fracture networks compartmentalization of the rock mass can occur with some areas not being hydraulically fractures. It has been inferred that litholigcally bound fractures may be unbound if a pre-existing fracture cuts the bounding layer. Complex geological layering, which tends to be horizontally oriented, overrides the physics that drives hydraulic fractures in the direction of the maximum stress trajectory (vertical direction).

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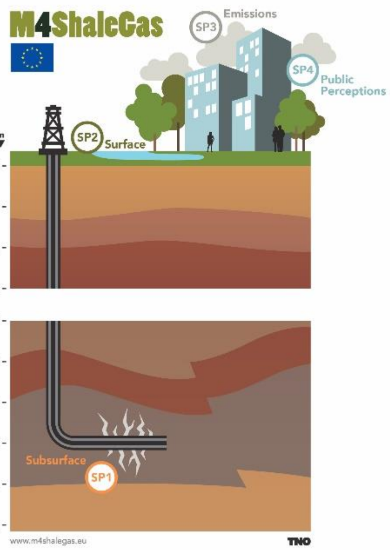
## Science-based Recommendations

- There is a strong need for well constrained data on properties of individual shale intervals. This dataset should include tensile strength, Young's modulus, compressibility, Poisson's ratio, and associated geochemical data including total organic carbon (TOC). A minimum requirement is to obtain indicative ranges of values for the major units of the sequence; it is preferable to have data on all units within a succession, including overburden (in order to quantify potential leakage pathways).
- During the exploration phase of a basin, a gap in understanding results from the general lack of suitably curated, well-preserved core material from depth, including that which has been obtained by pressure-coring to maintain the stress state of the samples. This also reduces the effects of drying, chemical, and biological degradation and is vital in order to compare datasets from the same shale gas play, or between different ones. It is desirable that core be retrieved in this manner and that the necessity for producing samples of sufficient dimension be considered when core logging and slabbing. Data that has been determined from dried, poorly preserved core needs to be identified to enable comparisons to be made between samples of similar quality.
- An understanding of the role (and cause) of variability and anisotropy in shale is required in order to assess hydraulic fracture initiation and propagation. The depositional facies, describing the cementation and diagenesis of the samples, should be recorded as this will allow comparisons between the same facies to be made. Where possible, representative samples should be taken throughout the interval of interest, to include mud-prone facies that may typically be poorly preserved upon retrieval.
- The full role of interfaces and pre-existing fractures should be determined so as to improve available modelling approaches. The physics driving deviation, arrest, slowing, branching, and lithological bounding of hydrofractures needs to be determined and incorporated into modelling approaches.
- Many numerical approaches exist; modelling should work towards a common approach of describing fracture propagation in shale, with a consensus sought as to what the minimum requirement is for baseline data that should be captured in order to gain the most comprehensive understanding of the mechanical behaviour of shale systems. Numerical models tend to over-predict the length of hydraulic fractures that have formed and that propagation is sub-vertical. Current understanding of fracture arrest in a complex geological unit, such as shale, needs to improve to numerically represent the hydraulic fracturing process.
- Shale gas site investigations should include both a regional context model and a detailed model of the rock mass at the point of stimulation. The model should include an assessment of stratigraphy and be attributed with physical properties (tensile strength, Young's modulus, compressibility and Poisson's ratio), stress state (magnitude and direction of the max/intermediate/min principal stresses, and pore pressure), fracture population, sequence stratigraphy, and associated geochemical data including total organic carbon (TOC). Some of these parameters cannot be obtained prior to exploration drilling and the models should be updated once data become available.
- A hydraulic fracture propagation model should be used to predict the initiation and propagation of hydrofractures. This should be continually revised as new information comes available, using observations of micro-seismic monitoring during stimulation to improve the model of hydraulic fracture growth.
- Regulation should include an independent assessment of all available data, their applicability, and observations of operations. Hydraulic fracture stimulation predictions should be scrutinised and an assessment be made of the likely breaching of sealing units. A thorough appraisal should be made of differences between that predicted and that observed by microseismic monitoring in real time during operations. The independent observer should have discretionary power to halt operations if the deviation from prediction is above a set threshold.
- All data obtained during exploration and stimulation should be lodged with the regulator, or national geological survey, and openly shared so as to create a publically available definitive database on shale properties.

## The Project

**M4ShaleGas** examines the potential environmental impacts and risks related to **shale gas** exploration and exploitation in Europe with the goal to build a technical and social knowledge base on best practices and innovative approaches for **m**easuring, **m**onitoring, **m**itigating, and **m**anaging these impacts.




**4 sub-programs:**

- SP1-subsurface
- SP2-surface
- SP3-air emissions
- SP4-public perceptions

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Understanding, preventing and mitigating the potential environmental impacts and risks of shale gas exploration and exploitation.

**Project duration:**
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**Coordination:**

TNO



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