**IEAGHG Fault Permeability & Overburden Studies**

**Fault Permeability - Project Outline**

**Geomechanical modelling**
- 1) dip tendency
- 2) fracture stability
- 3) dilatancy tendency

Numerous borehole studies support this approach but there is a lack of published material to support the hypothesis on a reservoir or regional scale.

**Fault Properties**
- Natural seams, mineralised fault zones, thermal & safety barriers
- Compartimentalisation of reservoirs & related pressure anomalies
- Fault fluid, large volumes of accumulated hydrocarbons over geological time – indicate sealing or very low permeability

**Fault Permeability - Factors**
- Fault complexity can include segmentation, bends, and so-called fracture connectingivity and fault permeability
- Inclined faults are highly anisotropic and heterogeneous properties that evolve through time
- Permeability can vary by 2 orders of magnitude over distances of m
- In situ permeability measurements are supported by numerical models which show highly non-linear behaviour
- Fault permeability can be highly sensitive to any change in the effective stress field and may be increased by raising reservoir pressure during CO2 injection

**Mitigation of Fault Leakage**
- Back production of injected CO2
- Hydraulic Fractures – model example CO2 CARE FRY
- Bemis,
- Microbially induced calcite precipitation – field tested
- Reactive group up using an asp sp of Na2CO3

**Fault Permeability - Factors**
- Lithostructure, composition and burial history also influential
- Faults can be hydrodynamically conductive & sealing at different stages of burial history

**Conclusions**
- Fault zone complexities produce variations, even over relatively short distances permeabilities can vary by as much as two orders of magnitude
- A range of fault and fracture properties, both hydrodynamically conductive and sealing, can be present in a single region
- Understanding the burial history of a fault is also important when considering its hydrogeological properties
- Fracture permeability generally decreases with depth
- Open fractures are most likely to modify fluid conductivity in low permeability caprock and can increase permeability by as much as 4 orders of magnitude
- High pore fluid pressures and preferential stress alignments are not a prerequisite for enhanced hydrocarbon productivity

**Key Take-Home Messages**
- Faults can either act as barriers to fluids, or as conduits for migration. Consequently, the properties of faults that do or do not form a boundary with potential reservoirs, need to be determined
- There is widespread experience of working with faults and fractures and provided there is sufficient characterisation of their properties they should not restrict storage development
- If fault zones are present they need to be correctly characterized to ensure the development of an effective containment assessment and to inform the development of operational constraints and monitoring plans
- A number of mitigation measures have been proposed to counter potential leakage

**Overburden - Project Outline**

**Rates of Migration**
- Evidence of rates of migration:
  - Measurement and modelling of CO2 flux from faults
  - Methane flux at natural seepage sites
  - Studies on well integrity
- **Difficulties constrain without permanent monitoring**
  - Fluid flow often slowly and temporarily variable
  - Can be modified by tidal events and earthquakes
  - Few datasets from actual wellsite leakages

**Conclusions**
- Prediction of hydrodynamically conductive faults and fractures preferably aligned with respect to the stress field is complicated by fracture healing whereby mineralisation of void space results in the stress independence of the fractures.
- The results of detailed fault studies and in situ permeability measurements are supported by numerical models which show highly non-linear behaviour and flow localisation
- Transient high permeability may develop due to high fluid pressures at depth resulting in episodic fluid flow
- Fault permeability can be highly sensitive to any change in the effective stress acting normal to a fracture plane and in some cases may be increased by rising reservoir pressures

**CO2 Storage Case Studies**

**Natural CO2 Seeps**
- Maximum CO2 flow rates for natural analogues of CO2 seeps associated with faults are generally ~0.1 tbur/d
- For these flow rates volumes of CO2 leakage could reach 10,000 tbur, which is similar to the 25,000 tbur estimated for a submarine seep (Papamoa, Greece)

**Key Take-Home Messages**
- Characterisation methods are currently identifying structures where the overburden fault form is able to explain potential migration paths with high probability
- Monitoring should be designed to detect leakages occurring near small surface areas with high temporal variability
- A range of sealing and non-sealing processes occur in the overburden this nature of which are not yet fully constrained e.g., whether a fault will form a barrier or flow pathway
- Understanding natural fluid migration in the overburden aids risk assessment especially attribution of faults

**Trapping Mechanisms**

**Research Projects**
- The UK Department of Energy and Climate Change (DECC) will use seismic and electromagnetic techniques to aid faulting and leakage mapping to test a number of high rank reservoirs in the South Devon, North Devon and Portland area as part of the UK EDIC funded CHIRP project. A geochemical and geological analysis of these benchmarks is being conducted within the framework of broader seismic data of the area.
- The ECOSTORE project demonstrated both short time frame driven flow in the sedimentary volume and also longer term stabilisation

**Leakage rates**
- Leakage rates
- 0.1 CO2 tbur/d
- 10,000 tbur/year

**Slieghner gas migration**
- We use evidence detected from changes in the pathway above the plane

**Mitigation**

**Case study - Krencha Gas Field**
- Field evidence of stress induced creation

**Geological Fluid Flow Features**
- Chimneys / pipes
- Flat non-reflecting mirror (polyethylene, reflector panel)

**Overburden**
- Defined as the entire geologic section above the topmost reservoir with which the overburden column forms the primary seal
- Focused on how to include the overburden in歧视 risk assessments
  - What are potential fluid flow pathways in the overburden?
  - What are the potential flow rates?
  - Are the overburden water chemistry characteristic?
  - What impact do these findings have on conducting storage risk assessments?

**Nets and networks modelled at depth**
- Review of the overburden at current and planned CO2 sites
- Review of working techniques and degradation rates and its utility
- Study of migration rates 7 controlled release experiments

**Stress Regime**
- A shift towards increasing stress strain, caused by increasing pore pressure, will eventually lead to shear failure.