N579: Understanding Faults and Fault Rupture – Applications to Fluid Trapping, Pressure Containment, and Induced Seismicity for Hydrocarbons and CCS *(Utah, USA)*

Instructor(s): Peter Hennings and Robert Krantz

Format and Duration

Field - 5 Days
Moderate Physical Demand

Summary

Faults occur in all subsurface reservoirs and are critical elements for the entrapment of fluids and fluid pressure at geologic and anthropogenic timescales. Faults are easily made to rupture associated with subsurface operations and therefore pose containment risk. Evaluation of trap and containment effectiveness and hazard assessment begins with an understanding of fault evolution and 3-D geometry. Understanding the ability of faults to trap fluids and pressure begins with a static characterization of fault permeability architecture. Fault containment hazard assessment requires transition to the dynamic realm with consideration of in situ stress and geomechanical behavior. The course is outcrop and classroom based. The Moab fault system and surrounding geology provide exceptional examples of trap-scale structures with fault zone characteristics that vary depending on offset and juxtaposed rock type, which are documented to have both sealed and leaked over geologic time in patterns that are clearly expressed. Reframing these outcrops to subsurface application is immensely valuable in understanding static and dynamic fault behavior.

Business Impact. This course provides an analysis-level treatment of fault geometry, characterization of trap effectiveness, and assessment of rupture hazard with application to hydrocarbon exploration, reservoir development and management, fluid pressure containment analysis for CCS, and induced seismicity hazard assessment.

Learning Outcomes

Participants will learn to:

1. Explain how faults form, displace and link in 2-D and 3-D.
2. Describe how fault systems evolve over geologic time.
3. Characterize controls on mechanical stratigraphy.
4. Apply 3-D fault framework interpretation methods.
5. Identify fault zone deformational fabrics and mechanics.
6. Develop reservoir compartmentalization models.
7. Differentiate static and dynamic fault seals, fault permeability and seal effectiveness.
8. Predict fault reactivation likelihood for application to seal failure, containment breach, and induced seismicity.

Training Method

This is a field course in Moab, Utah. Fieldwork includes visits to some of Earth's best-exposed and thoroughly studied outcropping fault systems, presentations, exercises and discussions (40%). Classroom sessions include lectures (30%) and laptop-based computer exercises (30%).

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Physical Demand

The physical demands for this course are MODERATE according to the RPS field course grading system. The fieldwork will involve walking up and down slopes over rough ground. There will be walks of up to 1.6km (1 mile) on most days, the most strenuous being an ascent (and descent) of 60m (200 ft) over rocky ground as part of a 3.2km (2 miles) walk. The altitude of the field area ranges from 1200–1750m (4000–5800 ft), which may lead to unexpected shortness of breath for some. Transport will be by SUVs on paved and graded dirt roads.

Who Should Attend

This course is intended for geoscientists and reservoir engineers who work with layered faulted reservoirs. Participants would benefit from having a basic familiarity with structural geology.

Course Content

Lectures, exercises and field visits will weave together three key subjects:

1. Interpretation
    - Applying “kinemechanical thinking” to interpretation
    - 3-D fault framework interpretation methods
    - Interpretation strategies
    - Recognition of faulting geometric and kinematic characteristics
    - Understand how faults form, displace and link in 2-D and 3-D
    - Understand how fault systems evolve over geologic time
    - Characterize mechanical stratigraphy controls
    - Identification of fault zone deformational fabrics and mechanics
2. Analysis
    - Understanding crustal stress and fault mechanics
    - Application of Andersonian faulting theory
    - Understanding Mohr-Coulomb failure analysis, rock strength and effective-stress
    - Predicting fault frictional failure
    - Understanding the importance of critically stressed faults
    - Predicting fault zone contents and properties
3. Application
    - Building complete fault framework interpretations
    - Describing structural evolution
    - Understanding of static and dynamic fault seals, fault permeability and seal effectiveness through time
    - Distributing fault properties and predicting leak points and flow barriers
    - Development of reservoir compartmentalization models
    - Predicting fault reactivation likelihood for application to seal failure and induced seismicity

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Itinerary (provisional)

Day 0

- Participants arrive at Grand Junction, Colorado, in the late afternoon and transfer to Moab, Utah

Day 1

- Introduction to faults, fault interpretation (classroom)
- Fault mapping in 3D (field)

Day 2

- Interpreting fault zones and fault rocks (field)
- Fault zone architecture, fault rock types and properties, predictive models (classroom)

Day 3

- Characterizing leaky faults (field)
- Fault mechanics, rupture, dynamic permeability (classroom)

Day 4

- Mapping and interpreting critical trap fault components (field)
- 3D structural frameworks, trap and containment assessment (classroom)

Day 5

- Integrated final project and course summary (classroom)
- Return to Grand Junction for late-afternoon flights home