Understanding Faults, Fault Seal and Fault Rupture: Applications to Fluid Trapping, Pressure Containment and Induced Seismicity, Moab, Utah (G058)

Tutor(s)

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Overview

This course provides an analysis-level treatment of fault geometry, characterization of seal 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. 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, and 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.

Duration and Logistics

6 days; classroom lectures (30%), practical exercises (30%) and field visits to some of Earth's best-exposed and thoroughly studied outcropping fault systems (40%).

The course is based in Moab, Utah, with participants arriving in and departing from Grand Junction, Colorado.

Level and Audience

Advanced. 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.

Exertion Level

This class requires a **MODERATE** exertion level. 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 100m (330 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. The weather should be pleasant with typical highs of 27°C (80°F) in the fall, but early morning temperatures may be below 5°C (40°F) and highs could reach 32° (90° F) on some days. Transport will be by mini-van or SUV on paved and graded dirt roads.

Objectives

You will learn to:

1. Describe fault geometry and how they form, displace and link in 2-D and 3-D.
2. Understand 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. Understand 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.

Course Content

Course Details

Faults occur in all subsurface reservoirs and are critical elements for the entrapment and compartmentalization of fluids and fluid pressure at geologic and anthropogenic timescales. Although some faults are stable over geologic time, they are prone 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, fluid pressures, and geomechanical behavior.

The manual will be provided in digital format and you will be required to bring a laptop or tablet computer to the course. Laptops will be used for practical exercises as well. Laminated posters will be used extensively in the field for annotation and discussion.

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

Day 1: Arrive in Grand Junction

Participants arrive Grand Junction, Colorado, in the late afternoon and transfer to Moab.

Day 2: Introduction to Faults

Classroom:

- Introduction to faults, fault interpretation

Fieldwork:

- Fault mapping in 3D; Northen Moab Fault (Courthouse and Mill Canyons)

Overnight in Moab

Day 3: Fault Zone Architecture

Classroom:

- Fault zone architecture, fault rock types and properties, predictive models

Fieldwork:

- Interpreting fault zones and fault rocks; Moab Fault (Arches NP) and Bartlett Fault Splay (Bartlett Wash).

Overnight in Moab.

Day 4: Fault Mechanics

Classroom:

- Fault mechanics, rupture, dynamic permeability

Fieldwork:

- Characterizing leaky faults; Little Grand Wash Fault (Crystal Geyser area)

Overnight in Moab.

Day 5: 3D Structural Frameworks

Classroom:

- 3D structural frameworks, trap and containment assessment

Fieldwork:

- Mapping and interpreting critical trap fault components; Northern Moab Fault

Overnight in Moab.

Day 6: Course Summary and Departure

Classroom:

- Integrated final project and course summary

Return to Grand Junction for travel home.