N016: Structural Geology for Petroleum Exploration *(Nevada, USA)*

Tutor(s): Ken McClay and Lans Taylor

7 Days	Competence Level: Basic Application

Field Course

Classroom Elements

MODERATE Moderate Physical Demand

3D Outcrop Imagery

Summary

This course examines aspects of structural interpretation in different tectonic regimes, from outcrop to regional scale, using field examples, petroleum industry case studies, seismic exercises and scaled analogue modelling examples. Key aspects of extensional, inversion and thrust tectonic regimes are described, analysed and reviewed in the classroom and at outcrop.

Learning Outcomes

Participants will learn to:

1. Appraise different tectonic regimes, to classify fault systems and to understand and evaluate the 4D geometries and evolution of fault systems in different tectonic regimes.
2. Recognize and interpret characteristic seismic expressions of different tectonic regimes as well as evaluate the tectono-stratigraphic sequences associated with different tectonic events.
3. Assess the fundamental geometries of extensional fault systems - planar and listric - in both 2D and in 3D, using analogues and field examples. Characterise fault geometries and fault sequences and their seismic expressions in different extensional environments from rift systems and passive margins to delta systems.
4. Evaluate and identify the distinguishing characteristics of inverted rift basins and the 4D geometric and kinematic evolution of inverted fault systems. Characterise structural styles of inversion and seismic expressions and assess hydrocarbon trap styles in inverted terranes.
5. Evaluate the fundamental dynamics and characteristic structural styles of strike-slip terranes and their 4D evolution. Assess models of 4D evolution of strike-slip fault systems and to recognize the seismic expressions of strike-slip fault systems.
6. Assess the 4D evolution of thrust systems, thrust wedge dynamics and thrust fault-related folds. Characterise structural styles of thrust and fold belts and the characteristic hydrocarbon traps in these terranes. To understand the dynamic evolution of thrust systems using scaled physical models. Interpret seismic sections in thrust and fold belts and to evaluate the 4D evolution of thrust fold systems using the analysis of syn-kinematic growth strata.
7. Critically assess and interpret field outcrops, seismic sections at the prospect and field scale by applying the concepts of geometries, kinematics and 4D evolution as given in this course. Evaluate seismic interpretations and map interpretations of different tectonic regimes.
8. Judge the effects of structural development on hydrocarbon reservoirs – reservoir compartmentalization, sub-seismic scale fault systems, fault and fracture networks, fault sealing concepts and the development of fractured reservoirs.

Duration and Training Method

A seven-day, combined field and classroom course in Southern Nevada. Field to classroom time is

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approximately 50:50. Lectures, practical exercises both in the field and classroom and discussion. Numerous seismic examples will be shown. Principles developed within the classroom will be illustrated in the field.

Physical Demand

The physical demands for this class are MODERATE according to the Nautilus Training Alliance field course grading system. The weather in southern Nevada is mostly dry and arid with mild to hot temperatures in April and May. The climatic conditions can vary greatly, so participants must be prepared for changeable conditions. The course has mostly short to moderate walks, with some over steep (up to 100 m ascent) and uneven ground. The longest walk is approximately 1.4 km (.87 mile). This class requires a good level of general fitness.

Transport on the course will be by SUVs. Most of the driving is on black-top roads, with some driving on graded dirt roads. One day includes a 30minute drive on a rough gravel road.

Who Should Attend

Geophysicists, geologists and engineers with an interest in the controls on structure and deformation from a reservoir to an exploration scale.

Prerequisites and Linking Courses

Familiarity with the basics of seismic interpretation and the principles of petroleum geology are an advantage (N085 Introduction to Seismic Interpretation, N090 Seismic Structural Styles Workshop, N005 Tectonic Controls on Basin Development and Petroleum Systems). N116 (based in Somerset, UK) has the same classroom content from Ken McClay.

There are a number of more specialist structural geology classes in the Nautilus Training Alliance portfolio which examine different stress regimes such as extension and rifts (N041: Utah, N295: Western Alps, France, N144: Gulf of Corinth), fold and thrust belts (N053, N325, N074) as well as topics such as fractured reservoirs (N134, N186, N337 and N109) and salt tectonics (N023 and N232).

Course Content

This course aims to familiarise participants with structural geological principles applied to extensional, compressional and strike-slip regimes.

The class will cover the following topics:

1. Tectonic regimes; fault systems and fault classifications; fault mechanics, fault rocks and fluid flow.

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2. Geometries of extensional faults – planar and listric faults; analogue models of extensional fault systems; rift tectonics and sedimentation; - extensional case histories – Basin and Range SW USA, Gulf of Suez.
3. Inversion tectonics; settings for inversion; geometries of inverted fault systems; 2D and 3D models of inversion structures; case histories of inverted basins.
4. Strike-slip systems; fundamental tectonic settings; 3D kinematic evolution of strike-slip fault systems; analogue modeling of strike-slip structures; natural examples of strike-slip fault systems.
5. Thrust systems; fundamental geometries of thin-skinned fold and thrust belts; kinematics of thrust systems; fault-related folding; growth strata in fold and thrust belts; hydrocarbon traps in fold and thrust belts.
6. Prospect and field-scale structural geology; fault sealing charcteristics; sub-seismic scale faulting and fracturing; structural compartmentalisation of reservoirs; fractured reservoirs.

The classroom lectures and presentations will show field, remote sensing and seismic examples of the key tectonic styles and fault systems. In particular they will be accompanied by scaled analogue models that demonstrate how these fault systems evolve through time.

Classrooom lectures and exercises will be complemented by directly relevant superb regional and outcrop examples in the field component of the course.

Please note that this itinerary may be modified depending on prevailing weather and light conditions.

Itinerary

The course is based at the Westin Lake Hotel, Las Vegas (east of Henderson near Lake Mead) for all 7 days of the course. The course will be a mixture of classroom days alternating with field days.

Day 0: Travel Day

- Participants travel to Las Vegas. That evening there is a short introduction to the area of study, a safety briefing and an optional group dinner.

Day 1: Extensional Tectonics and Extensional Fault Systems I

- Classroom lectures and exercises.
- Introduction to fundamental tectonic regimes; fault geometries and mechanics; extensional fault systems – planar and listric fault systems; rift systems;
- Seismic interpretation exercises.

Day 2: Extensional Tectonics and Extensional Fault Systems II

- All day field excursion examining extensional fault systems in the Muddy Mountains, Nevada. Echo

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Bay, Longwell Ridge and Lovell Wash – superb outcrop examples of extensional fault systems and syn-extensional sedimentation.

Day 3: Inversion Tectonics and Strike-Slip Tectonics

- Classroom lectures and exercises.
- Inversion tectonics and inverted extensional fault systems; inversion case histories. Strike-slip tectonics, strike-slip fault systems, analogue models and structural styles.
- Seismic interpretation exercises.

Day 4: Strike-Slip Tectonics, Inversion Tectonics and Reservoir Scale Deformation

- All day field excursion examining strike-slip fault systems and reservoir scale deformation in the Muddy Mountains, Nevada. Longwell Ridge fault system, Echo Hills – Bitter Springs fault system and the Valley of Fire.

Day 5: Thrust Tectonics and Thrust Fault-Related Folding

- Classroom lectures and exercises.
- Thrust tectonics; thin-skinned thrust systems; thrust fault-related folding; growth strata; analogue models of thrust systems; hydrocarbons and fold and thrust belts.
- Seismic interpretation exercises.

Day 6: Thrust Tectonics

- All day field excursion examining thrust fault systems in the Spring Mountains west of Las Vegas, Nevada. Keystone thrust system, Red Rocks State Park; Potosi Mountain thrust system; Spring Mountains thrust systems and backthrusts - with associated thrust-fault-related fold structures.

Day 7: Overflight of the field areas studied on the course

- Highlight of the course is a two hour overflight in a twin engined DH Twin Otter aircraft over the Spring mountains and over the Muddy mountains. This overflight gives the course participants spectacular aerial views of the structures that were studied on the field excursions and adds that invaluable 3D perspective and understanding of the key structural styles that are covered in the course.

After the overflight, participants are free to leave Las Vegas that afternoon.

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