





N114: Extensional Tectonics and Normal Faulting (*Nevada and California, USA*)

Tutor(s): David Ferrill

6 Days	Competence Level: Skilled Application
	Field Course
	Classroom Elements
MODERATE	Moderate Physical Demand

Summary

This advanced structural geology course provides geoscientists with hands-on experience analyzing complex structures at the reservoir scale. The course focuses on extensional fault systems but also visits sites with contractional structures associated with strike-slip fault zones. The course begins in Reno; traverses Owens Valley, Panamint Valley, and Death Valley; and ends in Las Vegas.

Learning Outcomes

Participants will learn to:

1. Appraise complex extensional structures analogous to those that control hydrocarbon migration and trapping in petroleum provinces around the world.
2. Evaluate subtleties of structural style.
3. Judge the strengths and weakness of interpretations of extensional fault systems.
4. Propose alternative interpretations based on the range of fault patterns observed.
5. Assess deformation mechanisms that operate in fault zones.
6. Evaluate and integrate structural uncertainty in risk assessment.
7. Characterize the regional tectonic setting, stratigraphy and development of the western Basin and Range, USA.
8. Judge how fault system geometry, timing and topology affect hydrocarbon migration and trapping.
9. Judge the complexity of fault scaling relationships (i.e. the interplay of fault displacement, length and timing).
10. Assess field examples of many of the extensional fault system features they will encounter during interpretation of seismic and well data.

Duration and Training Method

A six-day field seminar. The course is conducted principally in the field through observation and collection of data for exercises. A half day is spent in the classroom on the first morning in Bishop, California. On one evening, participants have the option to show posters or give brief presentations of their current work on extensional fault systems. The proportion of field time to classroom time is approximately 90:10.




Physical Demand

The physical demands for this class are MODERATE according to the Nautilus Training Alliance field course grading system. Field stops are in a mountainous, arid environment where temperatures range from cool to hot. The longest walk on the class is approximately 3 km (2 miles) with an ascent (and descent) of 300 m (1000 ft). There are walks of up to 1 km (0.6 miles) most days. Trails are generally smooth but can be rocky underfoot in places. The field area is at elevations from below sea level to 2500 m (8000 ft), which may lead to unexpected fatigue or shortness of breath for some participants. Transport is by SUVs. Most driving is on black-top roads, but some outcrops are reached via well marked dirt roads.



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The total distance driven on this course is about 1600 km (1000 miles).

Who Should Attend

The course is aimed primarily at experienced exploration and production geologists and geophysicists who are interested in improving their understanding of extensional structural elements.

Prerequisites and Linking Courses

Participants should have a basic understanding of structural geology principles. The Nautilus Training Alliance structural geology portfolio includes the following classes which may be of direct interest:

Basic Application level:

N016 Structural Geology for Petroleum Exploration (Nevada, USA)

N116 Structural Geology for Petroleum Exploration (SW England)

N090 Seismic Structural Styles Workshop

Skilled Application level:

N041 Extensional Tectonics and Normal Fault Patterns (Utah, USA)

N134 Carbonate and Shale Faulting and Fracturing Field Seminar (Texas, USA)

N142 Structure and Fault Systems in Hydrocarbon Exploration (Southern Pyrenees, Spain)

N144 The Corinth Rift: Normal Faults, Tectonics and Stratigraphic Architecture (Gulf of Corinth, Greece)

N288 Interpretation of Seismic Data in Structurally Complex Settings

N333 Rift Basins and Passive Margins: Examination of the Inverted Fundy and Orpheus Rift Basins on the Atlantic Margin (Nova Scotia, Canada)

Course Content

Exposures visited focus on extensional fault systems, extensional fault-bend folding, fault zone deformation mechanisms, fault scaling relationships and fault topology. The course also includes a broad overview of the structure of the western Basin and Range to provide regional context for the field localities.

Day 0:

- Fly into Reno, Nevada.

Day 1:

- Introductory lectures on the tectonic settings of the Western Basin and Range and extensional



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Field Course



Classroom Elements

MODERATE

Moderate Physical Demand

faulting concepts

- Depart for Bishop, California. Field stops to discuss structural style and regional tectonic setting
- Spend night in Bishop

Day 2:

- Morning lectures and exercises in meeting room at the White Mountain Research Center
- Basics of fault systems and fault topology
 - Series of exercises interpreting faults on structure contour maps of the Volcanic Tableland of increasing data resolution
 - Exercises interpreting fault gaps on high resolution structure contour map of single segmented fault
- Fault gap correlation exercise
- Drive to east flank of Sierra Nevada for overview of Volcanic Tableland
 - Discussion of regional tectonic setting of Volcanic Tableland
 - Discussion of stress and fault system development
 - Discussion of rollover geometry and growth faulting
- Volcanic Tableland field stops and exercises
- Evening poster session at the White Mountain Research Center: participants are encouraged (but not required) to bring a summary poster or brief presentation of a current project relevant to extensional tectonics to share with the group. This evening discussion may influence the focus of the balance of the trip.
- Spend night in Bishop

Day 3:




- Volcanic Tableland field stops and exercises
- Flipping faults
- En echelon fault array and relay ramps
- Southern Fish Slough fault system
 - Overview stop
 - Northern breached relay ramp - discussion of migration and trapping
 - Central breached relay ramp - investigation and discussion of internal deformation
- En echelon grabens in footwall of Fish Slough fault system
- Owens River cutbank crossing faults cross-section exposure
 - Cut and restore photograph of faults
 - Construct distance/displacement diagram
 - Discuss influence of small faults on reservoir permeability
- Spend night in Bishop

Day 4:



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- Drive from Bishop to Death Valley, stopping along the way to discuss Owens Valley, Eureka Valley, Saline Range, Saline Valley and Panamint Valley structural/ neotectonic setting
- Group 1 - Hike through Mt. Tucki detachment fault at Mosaic Canyon
- Group 2 - Hike through Death Valley normal fault on Natural Bridge trail.
- Spend night at The Oasis at Death Valley

Day 5:

- Group 1 - Hike through Death Valley normal fault on Natural Bridge trail
- Group 2 - Hike through Mt. Tucki detachment fault at Mosaic Canyon
- Kelley's Well Limestone Hogback, southeastern Funeral Mountains
 - Examination and discussion of contractional folds formed above very weak detachments during regional Basin and Range extension
 - Exercise to analyze and compare three different styles of contractional folding
- Lunch
- Steve's Pass – discussion of Crater Flat half graben and Yucca Mountain (proposed site of high-level radioactive waste repository)
- Bare Mountain – discussion of fault geometry and fault-block deformation processes in an extensional imbricate fault system
- Visit historic Rhyolite townsite (optional)
- Drive through basin-bounding fault on Titus Canyon Road (if time, weather and road conditions permit)
- Spend night at The Oasis at Death Valley

Day 6:

- Check out of The Oasis at Death Valley
- Drive to Dante's View
 - Overview of Death Valley regional tectonic setting
 - Discussion of regional pull-apart basins
- Drive to Badwater playa at range front between aggrading alluvial fans downthrown to Death Valley fault
- Copper Canyon and Mormon Point turtlebacks
- Lunch at "coal seam" near Shoshone, California
- Conclusion and drive to Las Vegas
- Depart from Las Vegas after 7:30 p.m. or overnight for departure the next morning