






N407: Predicting Reservoir and Petroleum Systems in Rifts and Extensional Basins (*New Mexico & Colorado, USA*)

Instructor(s): Lee Krystinik

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

Summary

Rifts and extensional basins often contain highly complex reservoir systems that can make your engineers pull their hair out; this course focuses on making economic sense from the geological complexity which is typical of rifts. Set in the scenic Rio Grande Rift between Alamosa, CO, Santa Fe and Albuquerque, NM, this course exposes geoscientists and engineers to modern and preserved examples of reservoir systems within an active rift basin. Major tectonic elements and a broad spectrum of depositional environments will be examined, including volcanic features often linked to "false positive" anomalies on seismic data in rift basins. Emphasis will be placed on predicting reservoir presence, morphology and quality, and spatial juxtaposition with seal and source lithologies. These observations directly impact completion technologies, reservoir characterization and plans of depletion and apply to many extensional basins.

Learning Outcomes

Participants will learn to:

1. Identify and predict reservoir systems common to rift basins each with its own issues for completion and reservoir engineers, including: Alluvial Fans and Fan Deltas, Aeolian Dune Complexes and Siliciclastic Sabkhas, Tributary and Axial Fluvial Systems, Lacustrine Shoreline and Deltaic deposits, Evaporative NaCO₃ Playas (similar to lake Magadi), Cyanobacterial Evaporative Source Rocks
2. Link these systems within the structural framework of rifting relative to basin bounding faults and lateral ramps along the axis of the rift and understand the engineering and development implications.
3. Understand the internal heterogeneities, juxtaposition and facies interrelationships among these systems within the context of economic recovery of the in-place reserves.
4. Predict typical reservoir spatial relationships and lateral continuity for the broad spectrum of clastic sedimentary systems in rift basins; this can have huge impact on project economics.
5. Construct predictive frameworks for rift fills from limited well log and seismic data.
6. Assess potential stratigraphic and structural trapping mechanisms in rifts to find new exploration areas and to determine bypassed opportunity in the more heavily explored parts of your basin.
7. Determine the appropriate ratio of potential reservoir vs. seal lithologies.
8. Develop predictive models for sandstone reservoirs in various locales within a rift basin. Engineering reservoir models must acknowledge rapid vertical and lateral changes in their reservoir.
9. Evaluate the economic application of key concepts and the difficulty involved in predicting play fairways across transfer faults.
10. Determine strategies for reservoir characterization, modeling, and ultimately designing a geologically driven plan of depletion within a rifted basin reservoir complex.




Duration and Training Method

This six-day field and classroom course starts in Colorado and ends in Albuquerque, New Mexico. The



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trip route will have multi-night stays in Alamosa, Colorado and Santa Fe, New Mexico. Participants will spend 80% of their time in the field, with interactive discussion of the implications for reservoir prediction and engineering considerations and how geological factors may impact the plan of depletion in a given reservoir. The daily itinerary includes conceptual lectures, subsurface exercises and observation of modern deposits and preserved outcrop examples to emphasize critical components in the evaluation of reservoirs in rifts and extensional basins. Four subsurface exercises will focus on various aspects of exploration and assessment in rift complexes. Training style will be guided group observations, with discussion of implications of these observations for exploration and exploitation.

Physical Demand

The physical demands for this class are MODERATE according to the Nautilus field course grading system.

The outcrops and observation points are generally 10-60 m (30-180 ft) of relief and most exposures are within 1 km (0.6 miles) of where the vehicles will park. Many exposures in the modern setting will entail examination of pre-dug trenches. Scrambling over rock outcrops and open terrain will be required, with all hikes being less than 4 Km (2.4 miles). The field area is at an elevation of approximately 2200 m (6600 ft), which may lead to unexpected shortness of breath for some. Temperatures in this part of New Mexico and Colorado are moderate in Spring and Fall, although weather can be as cool as freezing and as high as 30°C (85°F). Weather in Spring and Fall is typically dry, sunny and occasionally windy but rain and rarely snow or sleet may occur. Driving will be in SUVs on black-top and unpaved roads.

Who Should Attend

Geologists, geophysicists, engineers and other professionals engaged in production and/or exploration for clastic reservoir systems, especially in rift or extensional basin settings. Although the course is designed for experienced participants, those with less experience should also benefit from this course.

The course is also suitable for asset managers with responsibility for the exploitation of rift and extensional basin assets, in addition to technical support staff developing into the Geology and Geophysics disciplines.

Prerequisites and Linking Courses




It is recommended, though not required, that participants have a basic knowledge of the fundamental processes and terminology of clastic sedimentology, as is offered in N155 (Introduction to Clastic Depositional Systems: a Petroleum Perspective).

Upon completion of N407, participants may wish to consider these Skilled Application Level classes visiting similar settings:



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Reservoir modeling: N012 (Reservoir Modelling Field Class (Utah, USA)).

Sequence stratigraphy: N011 (High Resolution Sequence Stratigraphy: Reservoir Applications (Utah, USA)), N042 (Reservoir Sedimentology and Stratigraphy of Coastal and Shelfal Successions: Deltas, Shorelines and Origins of Isolated Sandstones (NW Colorado, USA)), and N451 (Practical Oil-Finders Guide to Siliciclastic Sequence Stratigraphy (Wyoming)).

Course Content

This course allows students to understand the scale and complexity of the interrelationships between the very diverse depositional systems that make up reservoir and source/seal systems in rifted and extensional basins. These complexities directly impact economics and reservoir engineering issues. Finding it and making it flow doesn't necessarily make it economic and this course addresses a number of potential pitfalls as well as pathways toward potential success. Systems to be examined are noted above in the Learning Outcomes. Reservoir and petroleum system prediction in rifted and extensional basins is the ultimate focus.

The modern system and outcrop examples are textbook quality but with real-world complexities. Participants will learn to work with the disparate data and observations common in these basins and to place them within a predictive framework for exploration and exploitation

Itinerary

Day 0

- Group flies into Alamosa, Colorado
- Pre-dinner reception: Introductions, Safety Briefing & Introductory Lecture : Overview of course objectives and the rift basin tectonic and depositional setting and their relative economic importance
- Overnight in Alamosa, Colorado




Day 1

- Breakfast Lecture: Breakfast Lecture: Alluvial, Aeolian and Sabkha Systems in Rifts – facies and reservoir behavior – overview of the rift basin tectonic and depositional setting and course objectives
- Alluvial fan observations from surface and excavated exposures
- Observation transect from proximal to distal and laterally on a modern alluvial fan and economic implications
- Aeolian Ergs, localization in rifts and fluvial interaction as seen at Great Sand Dunes National Park - observations of transverse dune systems, depositional locus and reservoir management issues.
- Trenches of facies, proximity to alluvial fans and braided feeder stream. Reservoir implications in



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volcanic-rich Aeolian sediments (the bad news and the good news for completion and reservoir engineers)

- Underfilled lakes/evaporative sabkha settings and link to petroleum systems in rifts.
- Modern observations of lacustrine setting, shoreline and fluvial input points
- Modern observation of Playas, cyanobacterial mats, salt pans, and early clay and silica diagenesis in Sodium carbonate brines (pH levels up to 13). Evaporative source rocks, alternative hydrocarbon source systems in other basins (stratified vs. oxygenated lakes, possible marine incursions).
- Overnight in Alamosa, Colorado

Day 2

- Breakfast Lecture on Axial Fluvial Reservoirs vs Tributary Systems
- Correlation exercise in axial fluvial reservoirs and the reservoir vs. seal dilemma and designing an evaluation approach for reservoir assessment
- Variable character of the channel belt within the axial stream along trend
- Trench exposures from a point bar in the river. Differences in the deposit down-flow along the point bar
- Quarry exposures of axial stream (paleo Rio Grande) deposits. Paleosols, older lake-margin deposits, mammalian burrows and homogenization of deposits.
- Marsh and peat deposits in marginal lacustrine environment.
- Fluvial, eolian, lake-margin and laminate central basin deposits in trenches along a major fault scarp and the implications for exploration opportunity and key observations for well spacing and engineering plan of depletion.
- Overnight in Alamosa, Colorado

Day 3

- Breakfast Lecture: Lateral change along the axis of a rift
- Traverse south along the Rio Grande Rift, across two sub-basins and visiting both margins of the rift and crossing the Rio Grande river several times, each in very different behavioral modes.
- Aeolian/Fluvial interactions in 11 million year old deposits. Aeolian and coarse fluvial systems along the rift margin and axis.
- Precambrian basement on margin of rift
- Massive basalt flows and the Rio Grande Gorge
- Major transfer zone and associated faulting. Fault systems and juxtaposition of reservoir facies along the margin of the Rio Grande Rift
- Overnight for days 3, 4 and 5 in Santa Fe, New Mexico




Day 4

- Breakfast lecture: Volcanic components of rifts and seismic “false positives”, Valles Caldera and the



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Bandelier Tuff

- Traverse the rift to Valles Caldera: Cultural stop at Bandelier National Monument
- Valles Caldera and secondary cones.
- Bandelier Tuff, basalt flows, sub-lacustrine flows, coarse bounding alluvial/fluvial systems.
- Overview of the rift, Rio Grande and small volcanic center and associated flows.
- Bandelier Tuff, basalt flows, sub-lacustrine flows, coarse bounding alluvial/fluvial systems.
- Free evening in Santa Fe.

Day 5

- Breakfast lecture and exercise: Integrating a reservoir model for rifts. Linking the rock observations to economic success
- Fault damage zone, physical and chemical components of potential seals and internal barriers to flow
- Overview of the rift and basin bounding fault from the west side of the rift
- Angular unconformity between pre-rift and syn-rift succession
- Fault controlled basalt dike intrusion along a small transfer fault
- Fluvial/Lacustrine(?) succession of “clean”, cobbly to sandy medium-grained, but diagenetically very dirty succession, fault damage zone and engineering issues. Walking in the footsteps of Georgia O’Keefe
- Overnight in Santa Fe.

Day 6

- Breakfast lecture on integrating a reservoir model for rifted and extensional basins. How do we apply this knowledge at the single well and field scale?
- Visit modern and ancient examples of the various reservoir facies along the margins of the Rio Grande Rift
- Alluvial fan traverse
- Major basin bounding fault and associated facies and tributary alluvial/fluvial deposits
- Rio Grande: Braided axial stream
- Ancient axial stream deposits
- Traverse across a large-scale eolian/fluvial/lacustrine basinal fill
- Field discussion and wrap up
- End of trip celebration and last night at the Hyatt Tamaya at the foot of a dormant volcano

Day 7

- Drive to Albuquerque for flights home