N359: Sedimentology and Sequence Stratigraphy of Aeolian and Mixed Fluvial-Aeolian Depositional Systems: Implications for Hydrocarbon Exploration and Reservoir Development *(Utah, USA)*

Instructor(s): Nigel Mountney

5 Days	Competence Level: Skilled
Field Course	
Classroom Elements	

Summary

This course aims to demonstrate and discuss a range of outcrop analogues that might be used to develop predictive reservoir architecture models for hydrocarbon systems located within arid climate, aeolian and mixed fluvial-aeolian successions. Specifically, this course will introduce a range of ancient sand dune systems that represent analogues for a variety of aeolian reservoir successions.

Learning Outcomes

Participants will learn to:

1. Evaluate various types of aeolian strata including facies types and geometry of architectural elements.
2. Assess the differences between wet and dry aeolian systems.
3. Estimate the distribution and 3D connectivity of high-permeability grainflow units within sets, as a primary control on overall reservoir quality.
4. Evaluate dry interdune elements and have an appreciation of their scale, geometry and reservoir characteristics.
5. Predict aeolian dune type from bed-set and bounding surface architecture and discuss techniques for reconstructing aeolian set geometries from 1D logs and core.
6. Estimate the 3D geometry of lower permeability interdune and dune wind-rippled plinth elements, their style of evolution over time and their likely interconnectivity.
7. Characterise the margin of aeolian erg systems and their style of interaction with adjoining fluvial channel systems.
8. Predict the relationship between fluvial facies to aeolian dune, interdune and sandsheet facies.
9. Validate the criteria for distinguishing between fluvial and aeolian facies in marginal environments with particular reference to the application of the criteria to core.
10. Assess the climatic controls on the accumulation and subsequent partial deflation of aeolian sequences and the formation of regional deflationary supersurfaces and their impact on reservoir quality and heterogeneity.

Duration and Training Method

A five-day field course comprising of introductory lectures will compliment the fieldwork. A number of field exercises will help provoke critical awareness of the major controls on likely reservoir units. The proportion of field time to classroom time is approximately 80:20.

Physical Demand

The physical demands for this class are MODERATE according to the Nautilus field course grading system. This is primarily due to the altitude (4,000-4,500ft/1000-1200m) and prevailing hot and dry conditions in the field area. There are moderately strenuous hikes on this class up to 3 miles/5km in

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length with less than 500 feet/200m of elevation gain. The remainder of the field stops involve walking a few hundred yards/metres with little significant elevation gain.

Who Should Attend

This course is designed for geoscientists, petrophysicists and reservoir engineers involved in exploring in continental settings and/or appraising/developing aeolian facies reservoirs. The lectures and exercises, as well as field discussions will integrate the various disciplines.

Prerequisites and Linking Courses

A familiarity with the basic theory of clastic depositional systems is an important prerequisite. The Basic Application Level Courses on the Nautilus programme covering this include N155 (Introduction to Clastic Depositional Systems: a Petroleum Perspective) and N156 (Clastic Depositional Systems in A Basinal Framework: Exploration and Reservoir Implications).

Linking courses include a variety of other field courses focusing on continental sedimentology, reservoir characterisation and modelling. These include N027 (Reservoir Sedimentology and Stratigraphy of Continental Clastic Systems), N202 (Characterising Continental Rift Infills: Depositional Analysis and Extensional Development of the Triassic Fundy Basin, Nova Scotia, Canada, N012 (Reservoir Modelling Field Class, Utah, USA) and M108 (Exploration and Geological Model Development in Fluvial Reservoirs, Ebro Basin, Spain).

Course Content

The course will comprise a field study of a range of ancient aeolian outcrop successions in southern Utah and northern Arizona. Study successions will include the Permian lower Cutler beds and Cedar Mesa Sandstone and their zone of interaction with fluvial deposits of the undifferentiated Cutler Group, the Permian aeolian White Rim Sandstone, the Middle Navajo Sandstone of the Glen Canyon Group and its zone of interaction with fluvial deposits of the Kayenta Formation, and the Upper Jurassic Entrada Sandstone of the San Rafael Group. The range and distribution of aeolian facies types and the style of large-scale architectural stacking of aeolian genetic units seen in these ancient examples will be compared with the subsurface deposits.

The field course will consider both the autocyclic (intrinsic) generation of complex aeolian set architectures as a result of bedform migration, and the allocyclic (extrinsic) response of desert systems to changes in climate, sediment supply and other related external factors, including various types of fluvial incursion into aeolian dune fields. The generation of regionally extensive “supersurfaces” forms the basis for erecting sequence stratigraphic frameworks for aeolian successions and represents an important, yet often mis-applied approach to correlation in the subsurface. In many of the field examples to be studied,

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chronostratigraphically-significant surfaces can be recognised over wide areas and can be traced from the central parts of aeolian dune fields (ergs) into marginal fluvial, lacustrine and sabkha sub-environments. Study at key field localities will demonstrate the procedure for the application of this approach in the subsurface as a field-scale correlation tool. The course will consider strategies for the interpretation of both vertical and deviated 1D well log and core data from aeolian and mixed fluvial-aeolian reservoirs and will demonstrate how the implementation of different facies models can result in radically different perceptions of interwell reservoir properties (sand body interconnectivity, net versus non-net, directional permeability etc).

lateral and vertical facies changes that have significant implications for understanding reservoir behaviour. Particular emphasis will be given to aeolian system type, with consideration of both “dry” and “wet” (i.e. water-table influenced) aeolian systems. The field course will demonstrate the interpretive power of adopting a sequence stratigraphic approach to correlation and will emphasise the ability of such an approach to predict the likely facies changes between spatial locations and the 3D geometry and size/volume of high poro-perm zones. Guidance will be given as to how a sequence stratigraphic approach might be used to contribute to the risk assessment of aeolian prospects, especially where regional palaeogeography is poorly constrained.

Additionally, the field course will briefly examine the role of structural heterogeneities at the reservoir-modelling scale. Faults as well as shear-failure features known as deformation bands are commonly found in aeolian systems and can act to degrade and compartmentalize otherwise excellent reservoirs. A thorough understanding of the spatial organization and orientation of these features is critical to successful exploitation planning and reservoir-modelling efforts, but this understanding is difficult to glean from larger-scale structures that may be apparent on subsurface data. The training course will demonstrate some of the structural controls on the localization of fault zone damage and the distribution of deformation bands, including halokinesis. Examples of aeolian successions that accumulated in salt-walled mini-basins will be examined and the impact of syn-sedimentary halokinesis assessed.

Approximate Itinerary:

Day 0: Arrival into Grand Junction.
Overnight: Grand Junction

Day 1: Fundamentals of aeolian-fl uvial systems and overview of the SW USA geological setting
- Aeolian strata from the Permian Cutler Group: introduction to aeolian facies types and their distribution within larger-scale sets of strata.
- Navajo Sandstone: consideration of criteria for the recognition of climbing sets of cross strata and an introduction to the key differences between dry versus wet aeolian systems.

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- Overview of the Paradox foreland basin and its largely non-marine fill.
Overnight: Moab

Day 2: Spatial complexity within a mixed aeolian-fl uvial system: The Permian Cedar
Mesa Sandstone-Cutler Group transition zone of Canyonlands National Park
- Mixed aeolian, fl uvial and near-shore succession of the lower Cutler beds.
- Aeolian erg centre location, consideration of facies types and geometry of architectural elements.
- Recognition of dry interdune elements and appreciation of their scale, geometry and reservoir characteristics. An opportunity to compare the dry 'erg centre' succession
with damp and wet interdune elements closer to the erg margin. Discussion on significance of low permeability baffl es and their role in partitioning reservoir intervals.
- Discussion of techniques for reconstructing aeolian set geometries from 1D logs and core.
- Techniques for the determination of the 3D geometry of lower permeability interdune and dune wind-rippled plinth elements, their style of evolution over time and their likely
interconnectivity.
- Consideration of the margin of the aeolian erg system and its style of interaction with adjoining fluvial channel systems.
Overnight: Moab

Day 3: Long-term temporal evolution of a largely dry aeolian system at erg centre and downwind margin and analysis of the distal part of a terminal distributive fluvial system:
The Permian Cedar Mesa and Organ Rock Formation of the southern Paradox basin
- Modern dunes with active slipfaces, grainfl ow strata, wind-ripple strata and adhesion structures on damp interdune surfaces.
- Aeolian-fluvial interaction in the Organ Rock Formation and the preservation of aeolian dune units intercalated with associated fl uvial sheet-like sandstone elements, aeolian
sand-sheets and calcrete palaeosols.
- Determination of the spatial extent of aeolian dune units and the nature of their contact with fluvial sheet-sand-dominated environments. Implications for reservoir scale, poro-perm characteristics and distribution of net versus non-net.
- Discussion of the origin of supersurfaces and the signifi cance of regional deflation events.
- Sedimentology of deposits associated with the supersurfaces and their impact on reservoir quality and heterogeneity.
Overnight: Moab

Day 4: Combined effects of both stratigraphic and tectonic heterogeneity: reservoir heterogeneity and partitioning at multiple scales
Navajo and Entrada Sandstone, Arches National Park

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- Series of group study exercises: approaches to the reconstruction of 3D aeolian reservoir architecture from outcrop and core data; consideration of limitations of the technique and required data.
- Approaches to the utilization of outcrop-derived data for constraining aeolian reservoir models.
- Permian White Rim Sandstone, Castle Valley Salt Wall.

Overnight: Moab

Day 5: Course overview and lessons for aeolian reservoir prediction

- Wrap-up session: General group discussion and refl ection on lessons learned.
- Drive to departure Airport (Grand Junction, CO).