An introduction to eolian deposition and hydrocarbon production

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Global distribution of Sand Seas (warm climates)
Global Hadley Cell Circulation

You were here

Penn-early Permian lowstand geography

The Minnelusa Desert
Aeolian Sand Sea formation: topography and wind interact to deposit sand over long periods of time, commonly off-on.

Figure 2 - Theme and variations on topographic traps for drifting sand. (1) Lee zone, (2) very shallow basin on desert floor, (3) wind weakens against obstacle, (4) loss of resultant wind energy near topographic uplands due to deflection of winds, (5) loss of resultant wind energy near an upland due to downslope (katabatic) winds. To a certain extent, this mechanism is found at Great Sand Dunes in the form of the east winds that blow back the dunes.
Aeolian Sand Sea formation: Depending upon distance of sand migration from source, trap-biased or source-biased sand seas can form.
Aeolian Sand Sea formation: Complex interactions of wind, rainfall belts, and water bodies also can form sand seas.

Minnelusa model?

Mauritania
An aeolian sand dune reservoir may be a single “pile of sand”. This may mask the true nature of the reservoir. The Wahiba Sands provide an interesting analogue for complex aeolian reservoirs.

Wahiba sand sea cross section
Aeolian reservoirs may consist of stacked sand seas formed at different times under different conditions.
Aeolian geography in a dynamic world: Dune fields interact with nearby depositional environments, producing complex sediment pedigrees.
All aeolian deposits are built of from four wind-created facies groups: Dune, interdune, sand sheet and sabkha.
Rapid changes in aeolian facies occur within a single oil or gas field, influencing recovery factors.
Dune Forms are very distinctive, and result from differences in wind regime.
Dune form and internal stratification increase in complexity as wind regime increases in complexity.
There are several ways to describe dune and other sets of crossbeds: using geomorphic, structural or genetic terms. It is important to keep this clear.
Internal stratification of aeolian dunes is a direct reflection of the wind regime and the growth seasons of the dune.

Libya, Linear dune
Aeolian sequences of bedforms tend to be incomplete.
Aeolian bedforms only rarely stack in perfect sequence. Slightly closer to the real world.
Poroperm domains of the Rotliegend distinguished on the basis of sedimentary environments of aeolian (dune), reworked (Weissleigend) and fluvial (wadi). (After Robinson, 1981).

Geologists and engineers realize that there are important poroperm distinctions driven by environments of deposition within the aeolian and other sedimentary domains. In this figure the poroperm qualities of interdune and dune are distinguished. (Martin and Evans, 1988)
Aeolian primary strata originate in wind variability

Figure 6 - Primary eolian strata and origins. A: Avalanche, B: Gravelfall, C: Ripple, D: Adhesion strata. Both Fig. 5 and 6 after Fryberger, et al., 1983.
Core from Auk Field, North Sea
Shows strong permeability contrast between ripple and avalanche strata

Auk Field
Depth (ft.)  Well 30/16-3

Tight, red-bed ripple strata

Porous, oil-stained avalanche strata

White, cemented, tight ripple strata
Auk Field Well A/ll-S2

Perm contrast compartmentalises the Auk Permian Reservoir, North Sea

Porous, permeable avalanche strata - oil saturated

Tight ripple strata – red-beds

after Fryberger, 2000
Primary strata bundles in Dunes and Interdunes: A source of sweep inefficiency

Fig. 18. Hypothetical, downwind-climbing, sinuous-crested eolian dune and interdune sequences. Note lateral and vertical variability in stratification type, preferred permeability components, and interdune barrier continuity. Cross-sections are in Fig. 19.

After Lindquist, 1988
Oil Flow barriers from primary strata and higher order breaks after Lindquist, 1988

Fig. 19. Depositional-dip and depositional-strike hypothetical porosity cross-sections for Fig. 18. Grainflow deposits (plain) are arbitrarily assigned a porosity of 15%; rainfall and wind-ripple cross-strata (coarse stipple) 10%; and interdune deposits (fine stipple) 5%. Note lateral variability and compartmentalization in dune “layers” and potential communication between layers because of interdune erosional removal.
Figure 8 Ideal orientation for slabbing to show maximum depositional dip and plugs oriented to best characterize directional permeability.

After Krystinik, 1990
Minnelusa Core
Raven Creek
Permeability anisotropy Nugget Sandstone after Lindquist, 1988

Fig. 9. Dune–interdune facies resolution. The two lower dune cross-set cycles distinguishable from stratigraphic dipmeter data are not easily resolved by porosity and permeability data because they are of the indistinct grainflow texture with reservoir properties similar to their associated interdune deposits. Also note the unusual directional dip variability (SE azimuth) in the porous Nugget cross-strata of the top cycle.
Aeolian reservoir fundamentals: Sweep efficiency Evaluated from core and dipmeter

After parsons, 1972 in Krystink, 1991

**Figure 9** Range of common $K_{\text{max}}/K_{90^\circ}$ ratios for eolian reservoirs; the impact upon directionality within the reservoir increases with the ratio.

**Figure 10** Drainage ellipses in reservoirs with the orientation of directionally-preferred permeability vs. orientation of a five-spot well pattern. The $0^\circ$ orientation achieves uniform depletion or sweep, whereas the $45^\circ$ orientation leaves a large reserve base unswept, assuming a central injector, (modified from Parsons, 1972).
Figure 11  Relative efficiency of sweep in a directionally-permeable reservoir. The 0° orientation achieves a high sweep efficiency prior to breakthrough, whereas the 45° orientation has early breakthrough of the injected fluid and very poor sweep efficiency (modified from Parsons, 1972).
Ras Al Ruways coast, Wahiba Sand Sea, Oman

Carbonate aeolian genetic units comprised of different facies groups are stacked along the Wahiba southeast coast in Oman. Dating indicates thousands of years between the Upper Dune Unit and the Middle Sand Sheet.
Early Models of Sweep based on Ras Al Ruways cliffs after Hern, 2012
Ras Al Ruways outcrops of Wahiba Sands, Oman:
Stacked sand seas

After Fryberger, Hern and Glennie, 2012
Crossbed model of Ras al Ruways outcrops, Wahiba Sands, Oman

Fill

Dune buildup

Upper dune Unit

Middle Sand Sheet

Lower Dune Unit

Transverse primary bedform with superposed barchan bedforms

Carapace of low effective permeability interval resulting from migration & infill of geomorphic accommodation space by smaller, faster moving bedforms

SBED Model by Caroline Hern
Sweep model based on Wahiba Sands outcrop
after Fryberger, Hern and Glennie, 2012

Model by Caroline Hern
This sandstone is very similar to that described for #423. Very fine to fine grained sand dominates the sample, with thin (one to two grain thick) laminae of typically medium to coarse (lower) sand. Note that although the laminae are discontinuous, they do not appear to grade laterally, typically passing directly into the very fine grained sandstone. Haematised clay coatings are common on grains (a), and more clay-rich finer laminae are present. Finely crystalline blocky kaolinite cement is widespread, with only some secondary macropores being left uncemented, giving the rock its very poor permeability. Dolomite is common as a finely crystalline (c. 20mm crystals) cement dispersed through the sample. Quality is controlled by the very fine to fine grain size and the kaolinite cementation, with a lesser impact of dolomite.
A non-haematised fine grained, moderately packed sandstone with a massive fabric. Sorting is good. Most grains have a thin grain coating (?illitic) clay rim, whilst the pore system remains relatively clean, apart from common relict material derived from feldspar dissolution. Kaolinite forms a common cement, both in a typical blocky to vermiciform character (c. 20-30 mm), and also the more coarsely crystalline (c. 30-60 mm) bladed variety which forms spherulitic aggregates in pores. Dolomite forms common, relatively large (c. 30-100 mm) crystals dispersed through the rock (a). The pore system is mixed macro- and microporous reflecting a relatively clean sandstone, partially but not totally cemented by kaolinite and dolomite. The uniform fine grain size is largely responsible for the relatively good quality (9.93mD), but the key to maintaining this quality appears to be the high microporosity within the kaolinite cement, which allows restricted fluid flow through it to connect the patchy macroporosity. 0.5mma